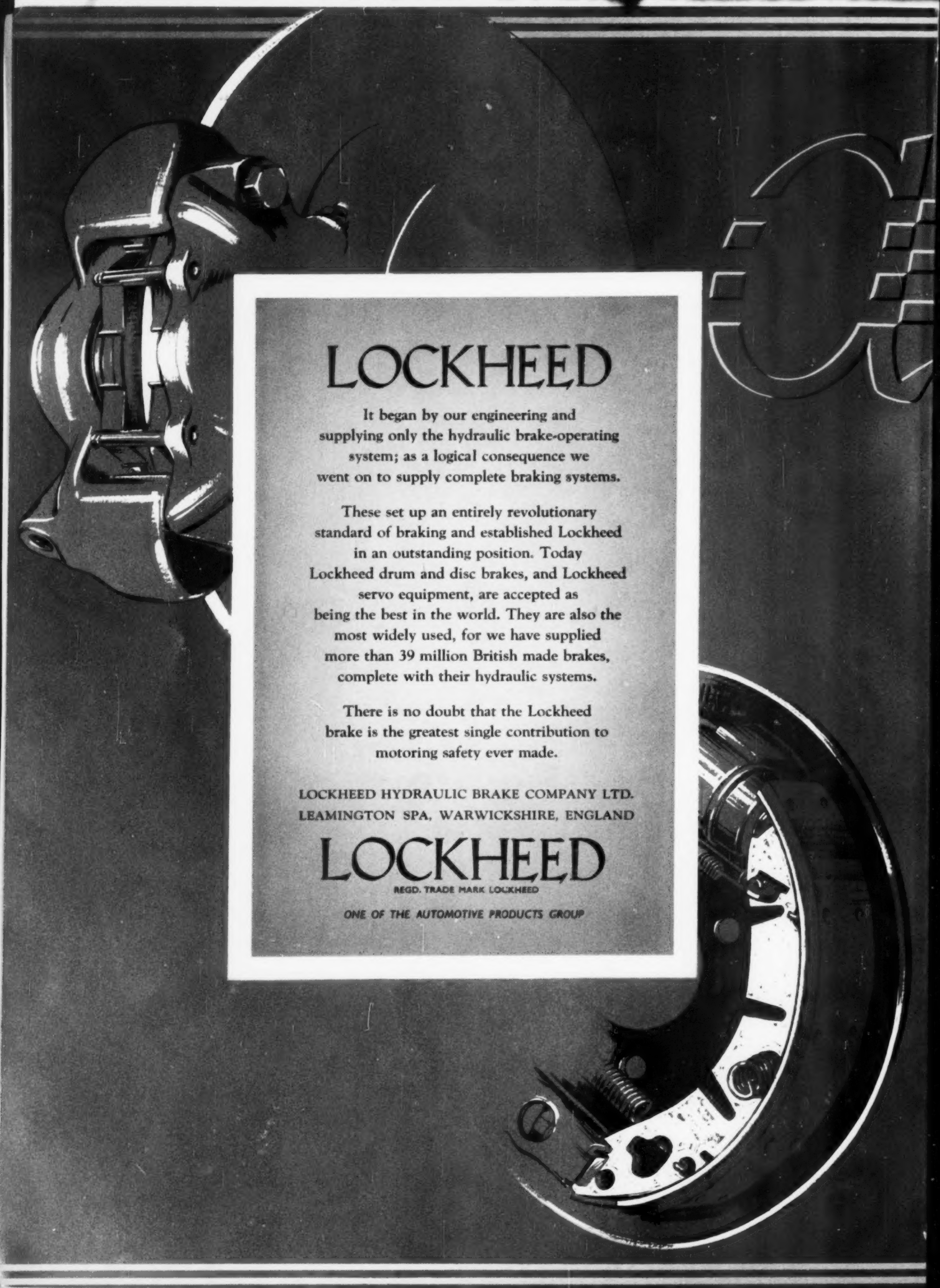
THE GOLDEN JUBILEE OF

AUTOMOBILE ENGINEER

DESIGN · PRODUCTION · MATERIALS

Vol. 50 No. 6 JUNE 1960 Price 3s. 6d.


LOCKHEED
It began by our engineering and supplying only the hydraulic brake-operating system; as a logical consequence we went on to supply complete braking systems.
These set up an entirely revolutionary standard of braking and established Lockheed in an outstanding position. Today Lockheed drum and disc brakes, and Lockheed servo equipment, are accepted as being the best in the world. They are also the most widely used, for we have supplied more than 39 million British made brakes, complete with their hydraulic systems.
There is no doubt that the Lockheed brake is the greatest single contribution to motoring safety ever made.
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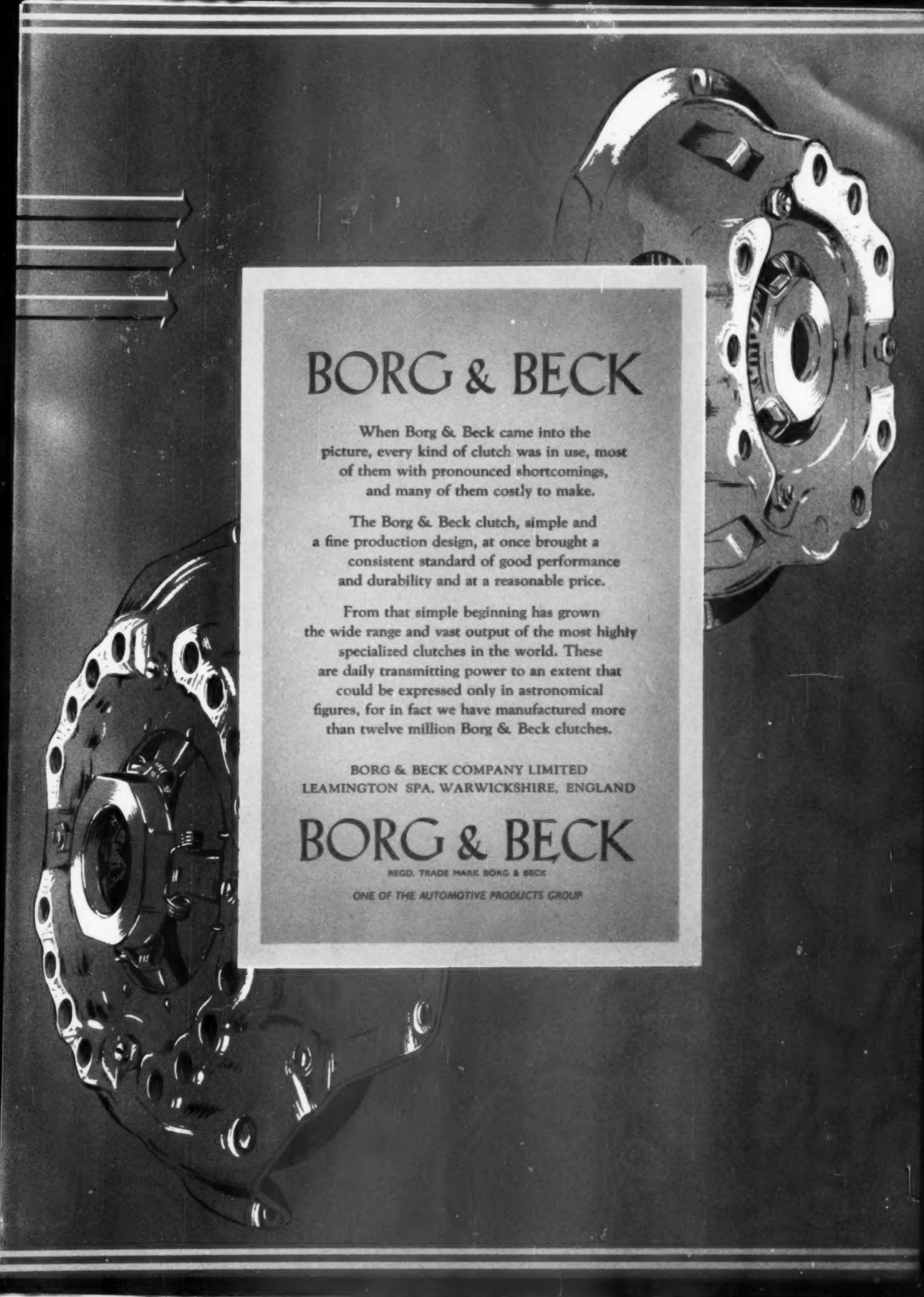
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When Borg & Beck came into the picture, every kind of clutch was in use, most of them with pronounced shortcomings, and many of them costly to make.
The Borg & Beck clutch, simple and a fine production design, at once brought a consistent standard of good performance and durability and at a reasonable price.
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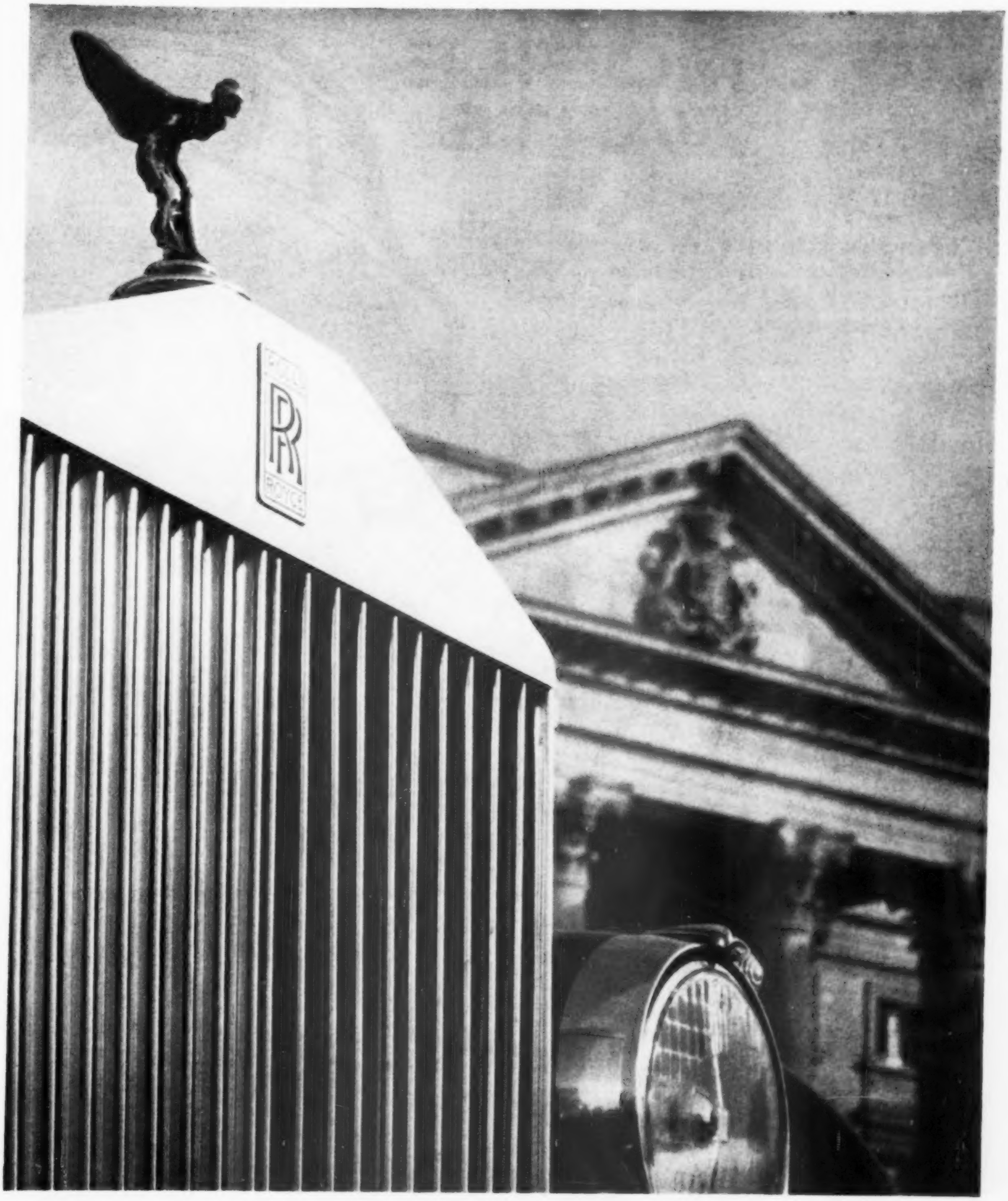

For Extreme Accuracy and High-Production Surface Grinding . . .

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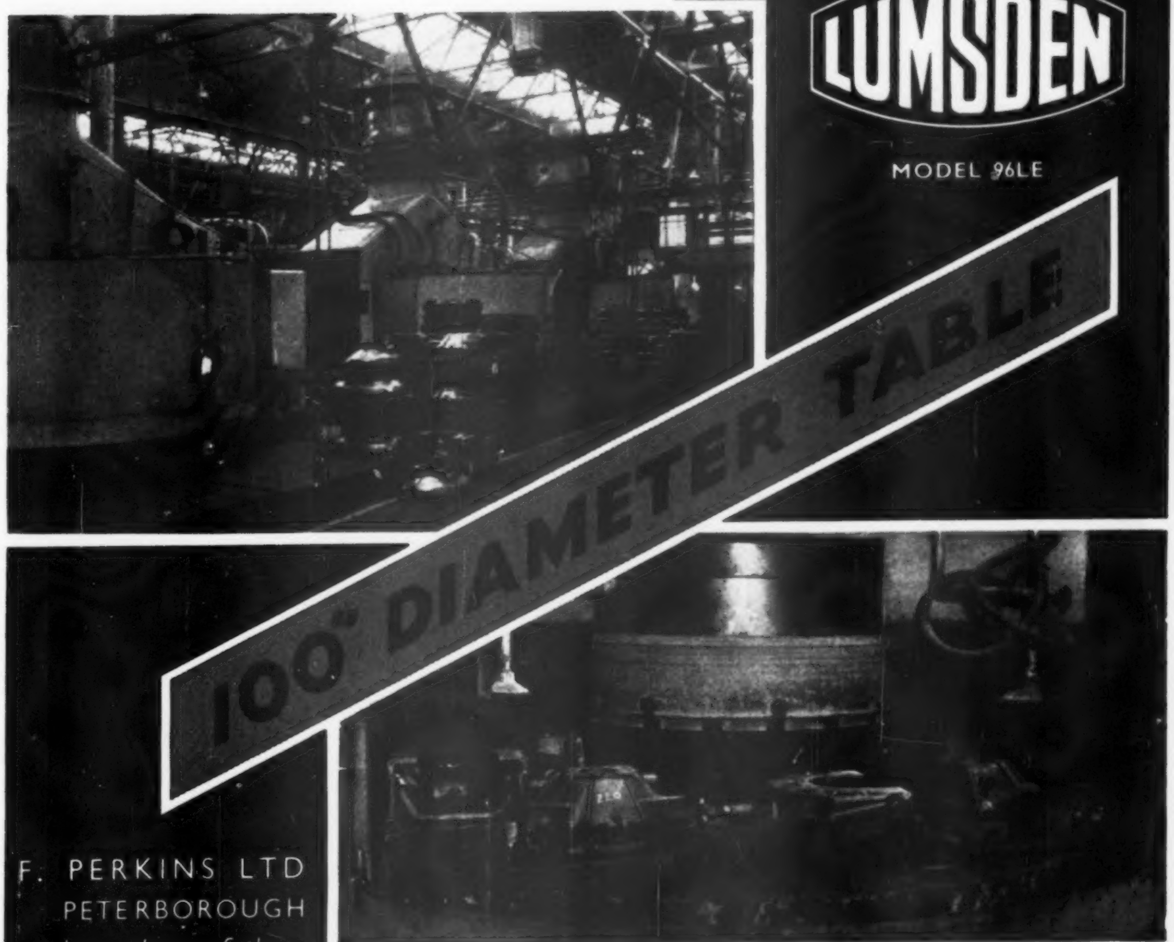

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have three of these machines installed at their Eastfield Works . . . .

Grinding eight clutch housings of the 'P' series engines; four housings located for grinding gearbox face and four for grinding engine face. Total time—43·2 mins., thus each housing is ground on both faces in 10·8 mins.
Material is cast-iron. Stock removal up to $\frac{3}{16}$" from each face.

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Spindle speed 300 r.p.m.
Other table sizes available from 24" diameter.

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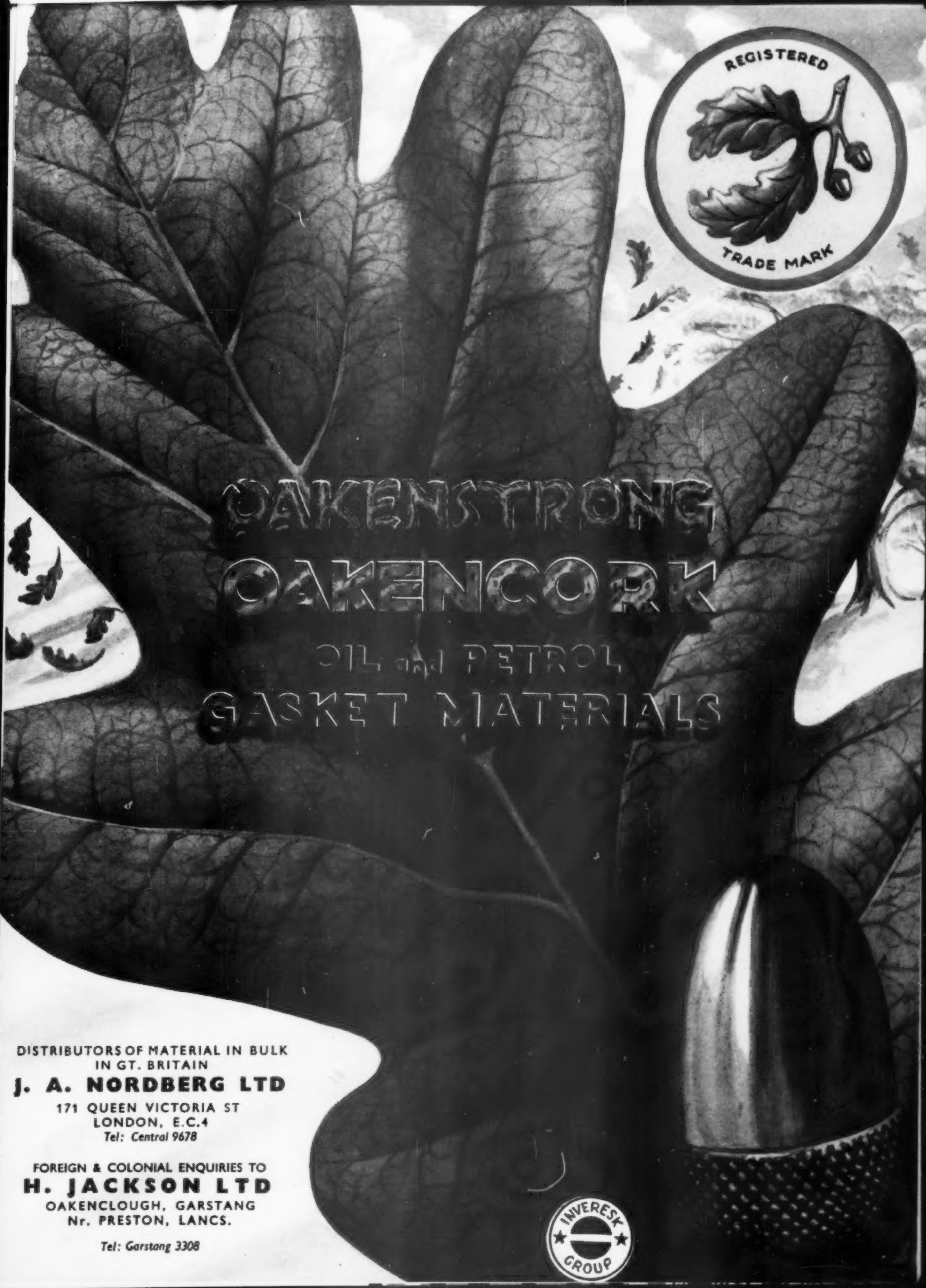
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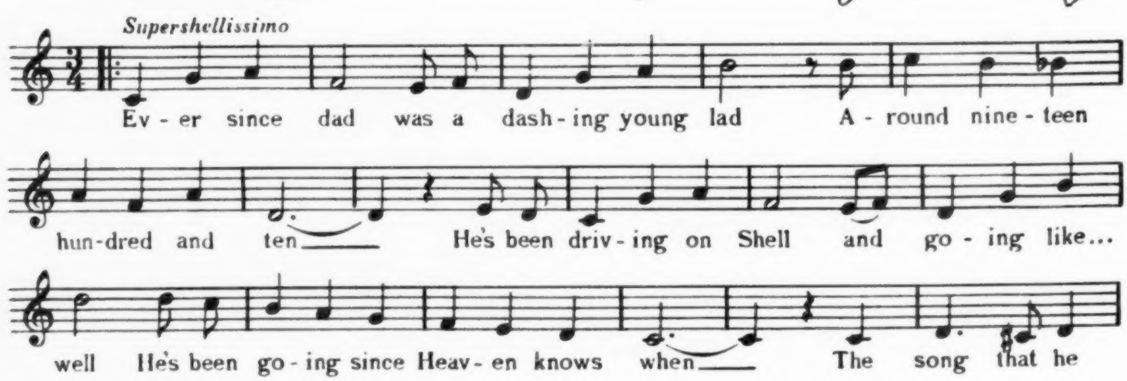
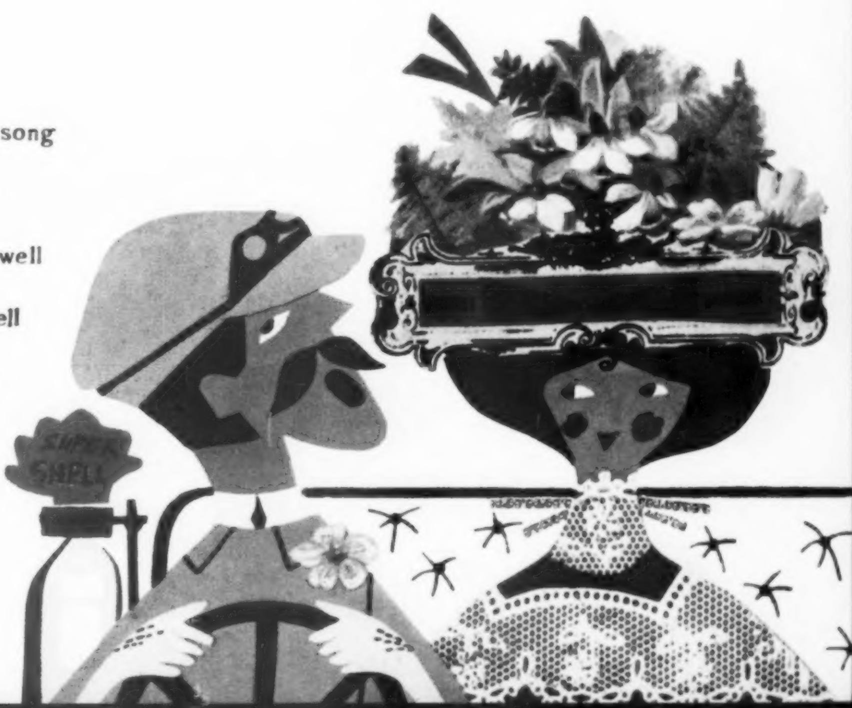


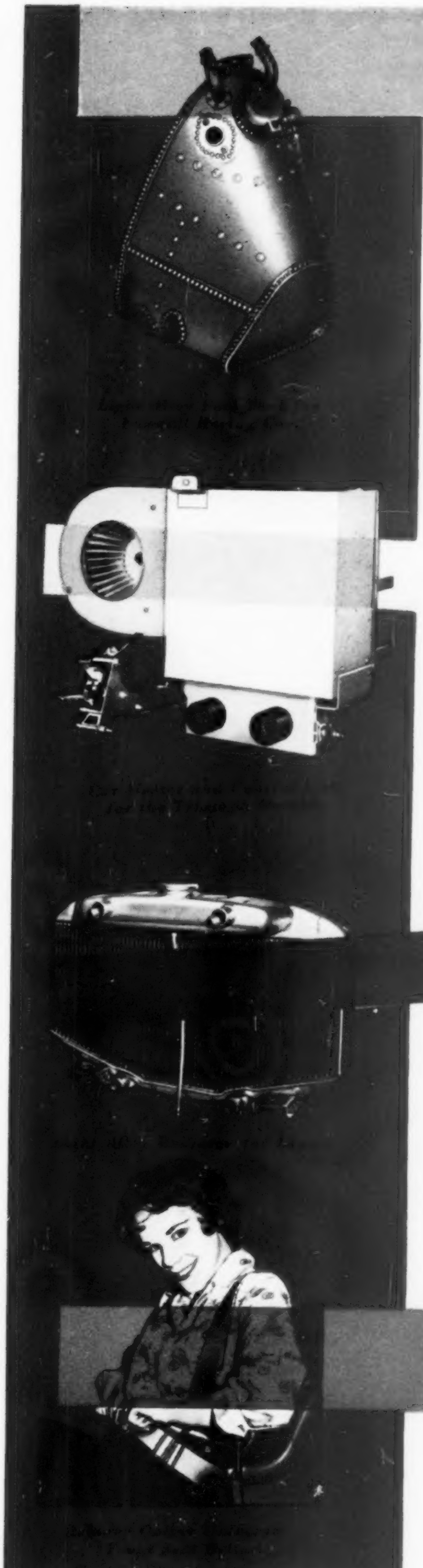
VERSE 2

Grandmama darling please answer my song
I've sung it for nigh fifty year
I've waited my darling all my life long
Drive with me grandmama dear
I'll give you sunshine and moonshine as well
I'll feed you on fine caviare
I'll give you gallons and gallons of Shell
For our own little aut-o-car
So he sings this refrain loud and clear
And he sings it right in grandma's ear

REFRAIN

Please come away in my aut-o-car *etc.*





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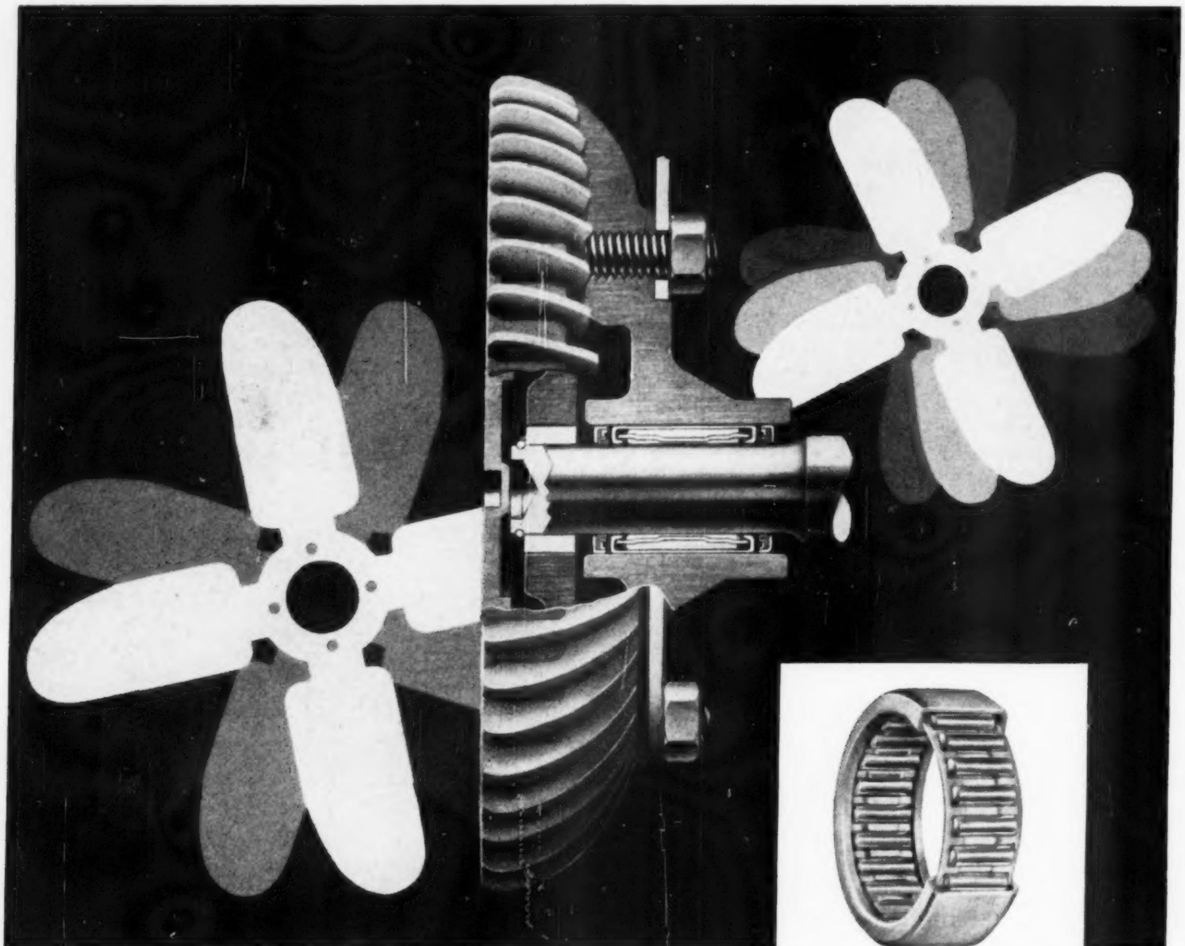

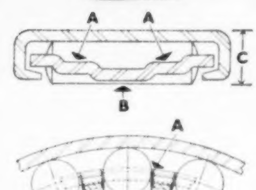

- *rollers end-guided at pitch line (A)*
- *shaft-riding retainer (B) designed to permit lubricant circulation*
- *high capacity in small cross section (C)*
- *efficient at high speeds*
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Torrington can provide it. The design of the automobile engine fan illustrated above called for two ball bearings to reduce fan horsepower and noise. By replacing them with one Torrington Drawn Cup Roller Bearing the customer has simplified the design and reduced costs.

This bearing firmly supports the drive housing and fan, so that they run true despite possible couple loads due to gyroscopic action. Ample lubricant reserve capacity permits pre-lubrication for the life of the fan drive.

Many new opportunities for economy, design simplification and operating improvements are opened up to engineers and designers by the new Torrington Drawn Cup Roller Bearing. The services of our Bearings Division are offered to help you with your development work.

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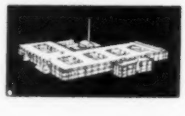

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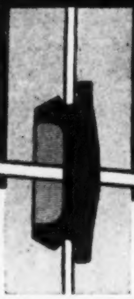


infinitely accommodating in use: considerably reduces range of sizes because the same grommet can be used with several plate thicknesses or cable sizes

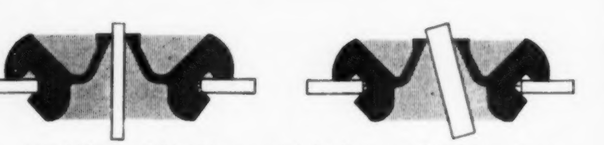
PAT. APP. No. 5255/59

This newly developed self-conforming grommet, because it is immediately self-locking against the elements, is the solution to many of an engineer's sealing problems.
Any one size will not only accommodate itself to a variety of mounting plate thicknesses, but (designed for cable or control rod) will take these in a variety of sizes and be weather-, water- and dust-proof at a variety of angles to the cable or rod.

Because of its capacity to conform to many varying requirements, it enables a workshop stock range of grommets to be reduced to perhaps one tenth of that at present maintained.

Note how when sprung into position the grommet provides a perfect double seal by its own permanent pressures. The angled groove also creates a tight pressure hold on the metal plate.

In the cable grommet variety the same double pressure seal is created, allied to tight seal on various diameters of cable. This new grommet gives sound sealing at *all* vital points.



A useful feature of this cable grommet is that by reason of the designed taper of the cable entry and the flexibility of the web, a considerable angle of cable entry and a variety of cable size are possible. This avoids necessity for special grommets with angled bores.

In the conventional grommet, only one thickness of plate and only one size of cable can be accommodated. No effective seal is afforded by the parallel groove.

Now being produced in a range of sizes.

THESE GROMMETS WILL SOLVE YOUR SEALING PROBLEMS.

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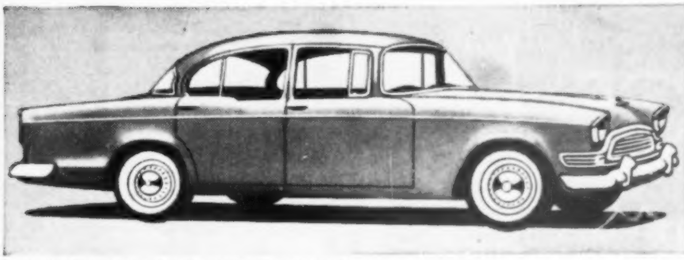

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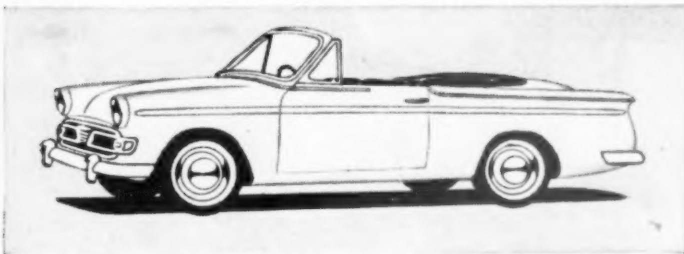
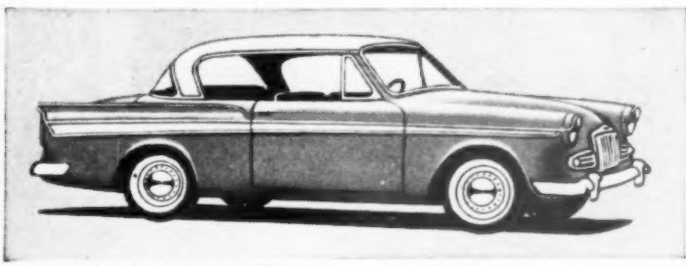


HILLMAN MINX CONVERTIBLE



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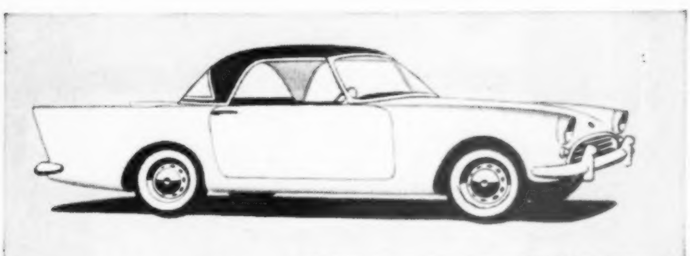

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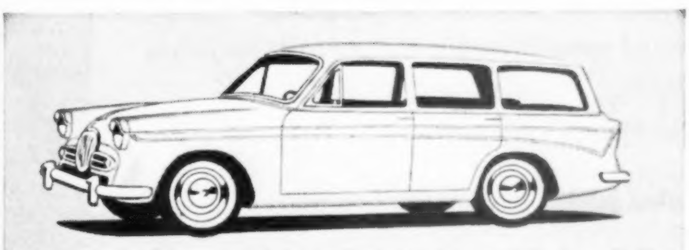

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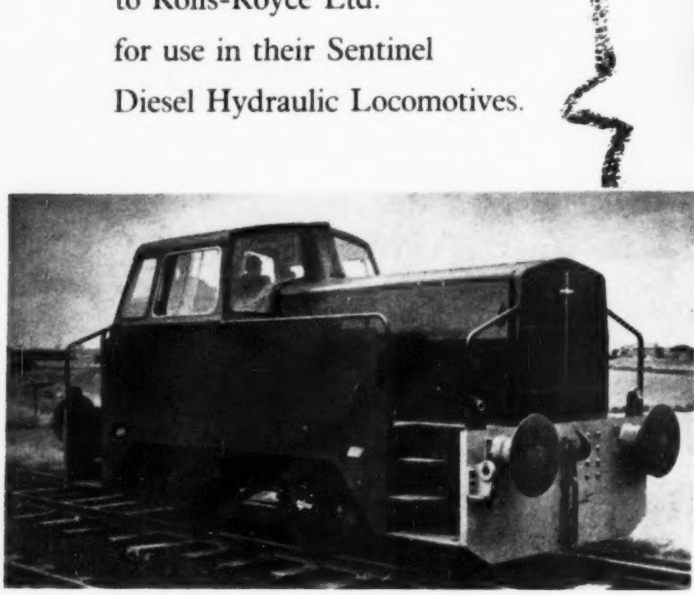
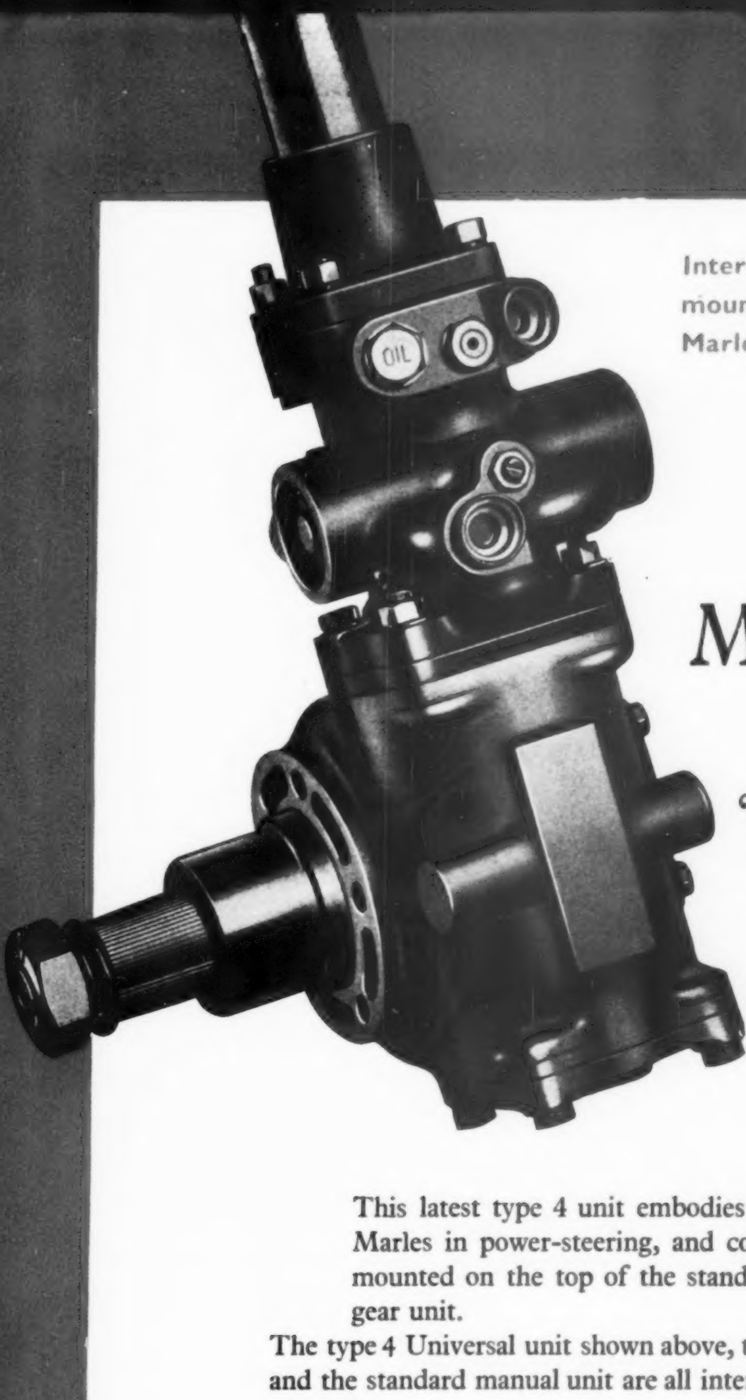


Sentinel Diesel-Hydraulic locomotive with Rolls-Royce engine and Torque-Converter.



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The type 4 Universal unit shown above, the type 3 Universal unit and the standard manual unit are all interchangeable on the same mountings.

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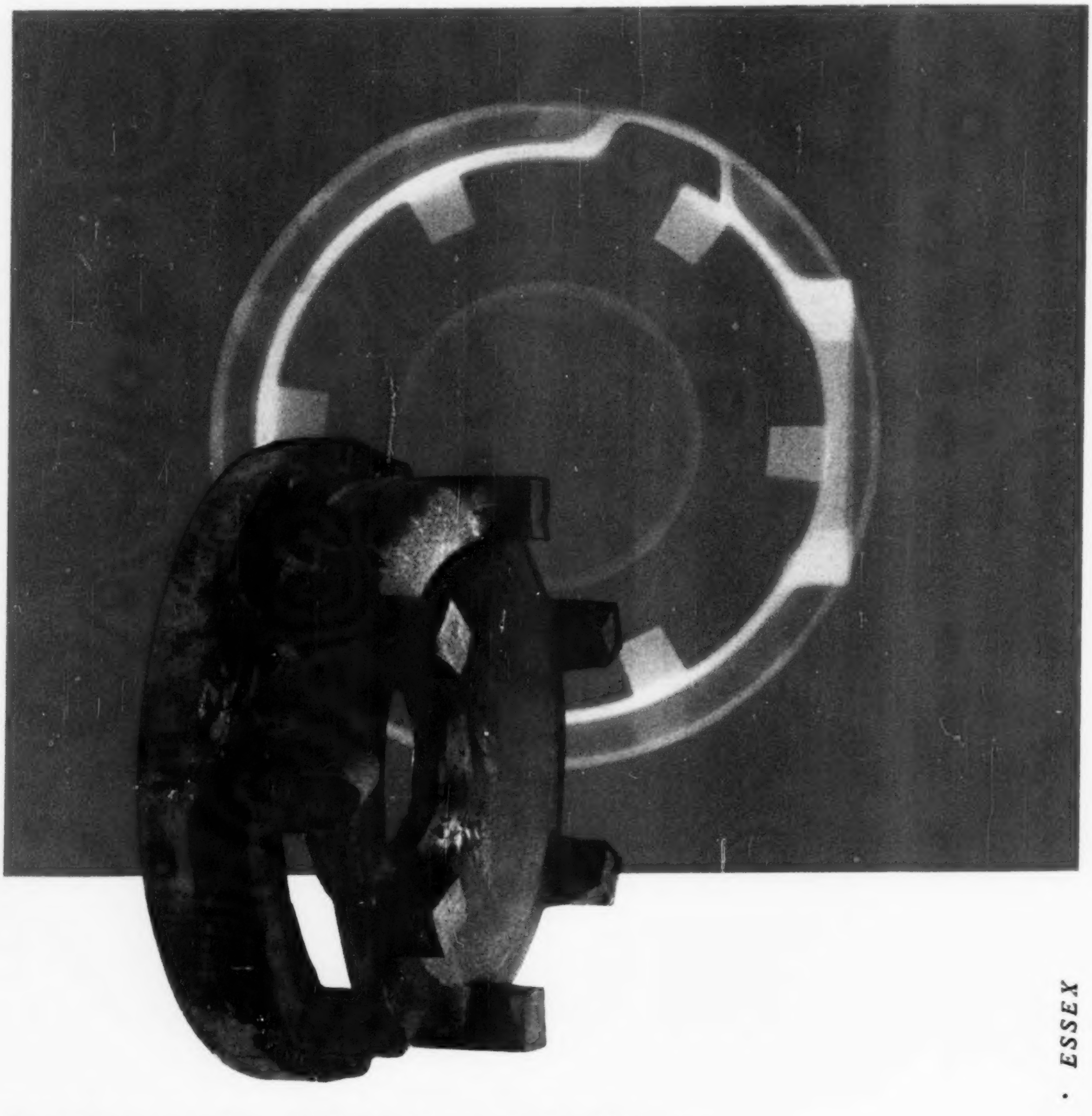

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DU PONT NEOPRENE has outstanding resistance to ozone cracking. Du Pont neoprene has proved under test, and on the job, that it is vastly superior to natural rubber—and to "general purpose" synthetics. Neoprene resists oil and grease in the chassis . . . high temperatures under the bonnet . . . oxidization and aging of exposed parts and accessories. Properly compounded neoprene products meet most service needs at temperatures ranging from —54 C to as high as 121 C. Compounds can be made soft or hard and in sponge form. **HYPALON*** synthetic rubber has even greater heat and ozone resistance and is known for its remarkable colour stability, permitting use of bright colours for weather stripping and convertible tops. Hypalon doesn't become brittle in cold weather nor will it crack under heat or summer sun.

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The Murex "Fastex 5" electrode has many features which make it the best welding electrode for most jobs. It has exceptionally smooth running properties and general ease of operation in all welding positions. These are combined with low weld spatter and self-detaching slag. All these advantages ensure that high quality welds can be readily obtained for all general fabrication work, with neat and regular weld bead appearance and with freedom from undercut. Although primarily designed for flat and horizontal-vertical welding, the "Fastex 5" electrode can be used in all other positions and is acknowledged by experienced engineers throughout the world as the best general purpose electrode for welding mild steel.

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you feel you're driving a better car
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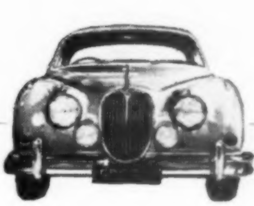

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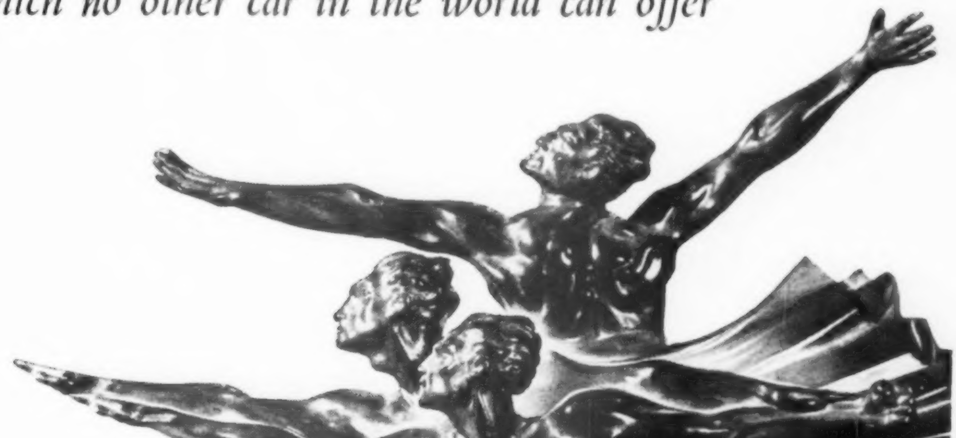
which no other car in the world can offer



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One of the Trophies won by Jaguar in their Le Mans victories of 1951, 1953, 1955, 1956, 1957

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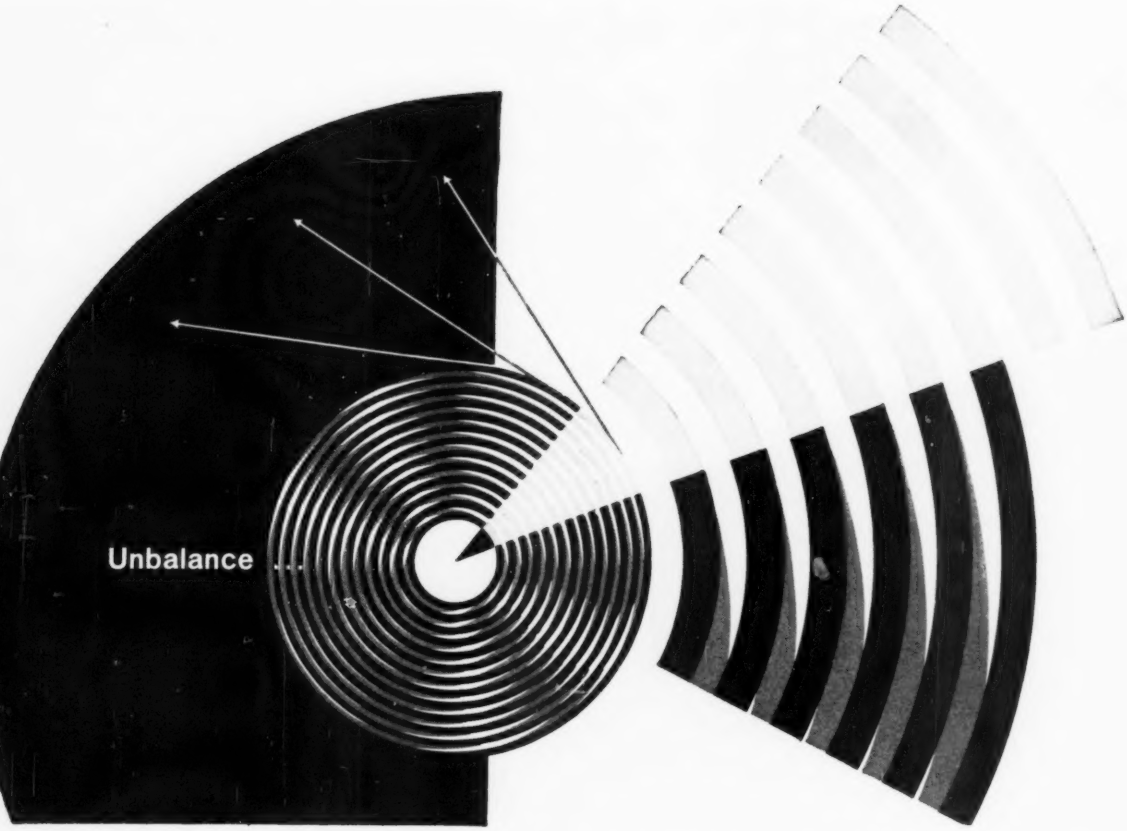
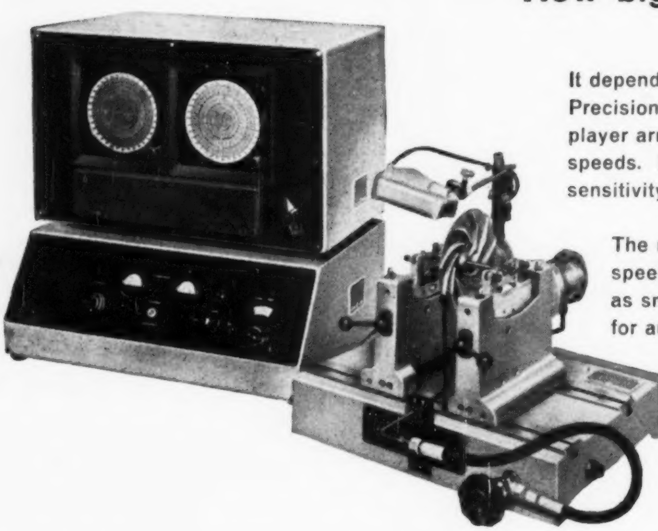


How big is your safety margin?



It depends largely on the operational speed of the rotor. Precision parts like electric Gyroscope rotors, or record player armatures, require very delicate balancing at high speeds. Fortunately, the higher the speed, the greater the sensitivity of a dynamic balancing machine.

The machine shewn will balance small rotors at speeds up to 60,000 r.p.m., and detect displacements as small as 0.002μ. This is ample margin for any application.

At the end of the balancing run, the information remains displayed on twin vectormeters. The position of a light spot on a polar diagram shows the angle, and the radial displacement of the light spot shows the amount of unbalance.

Please ask for further information, quoting reference AE3

AVERY for ELECTRODYNAMIC BALANCING

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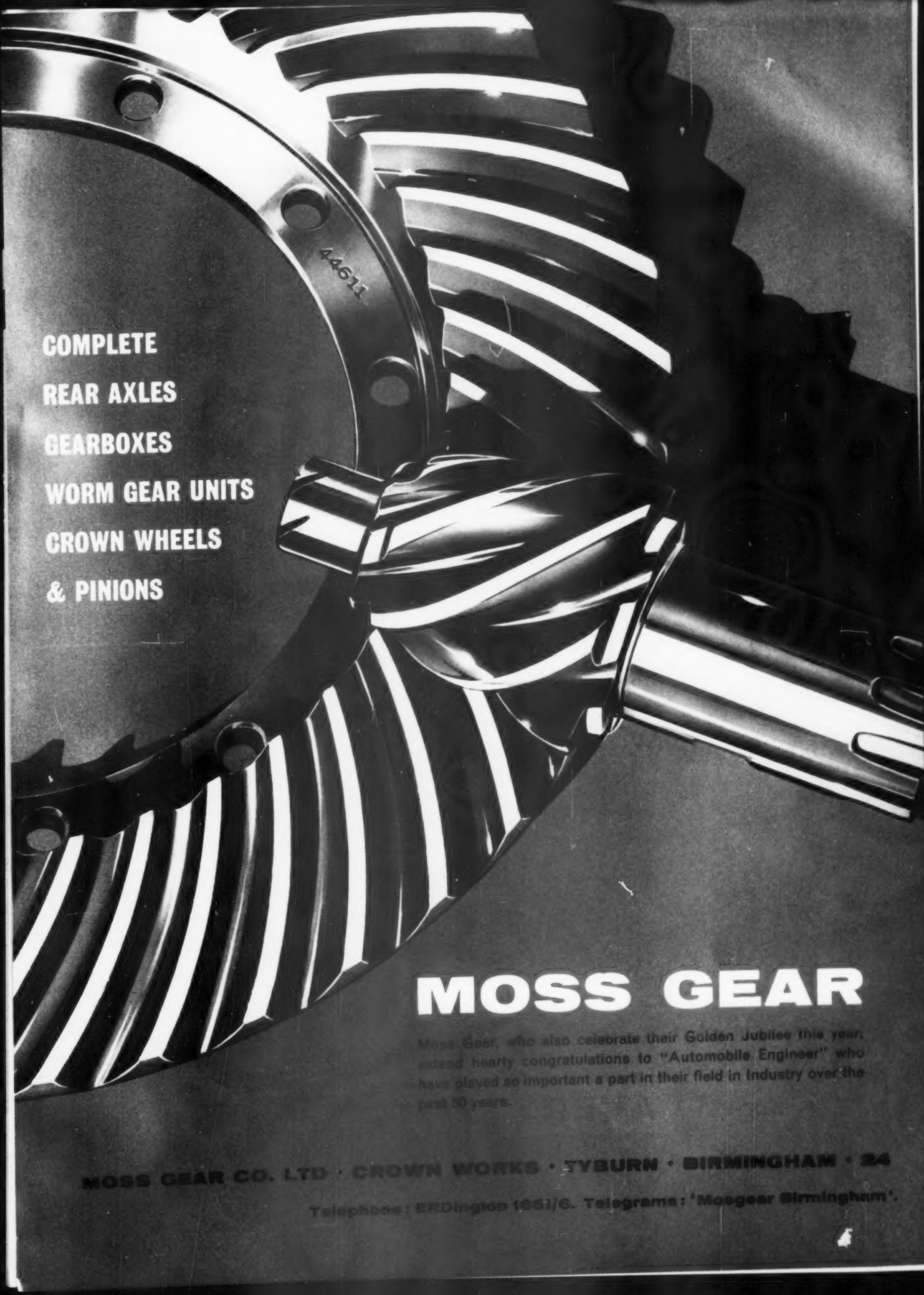

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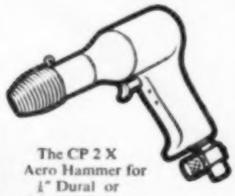
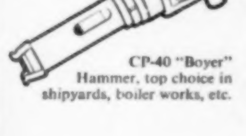
HERE ARE 6 DIFFERENT CP RIVETERS



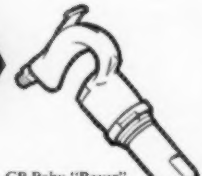
The CP 2 X Aero Hammer for $\frac{1}{4}$" Dural or $\frac{3}{16}$" steel rivets.

The CP 4 X Aero Hammer with Pistol Grip handle for $\frac{1}{4}$" Dural or $\frac{3}{16}$" steel rivets.

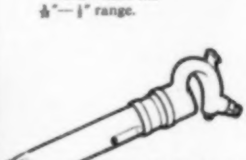
CP-2044 one shot Hammer $\frac{3}{16}$" Dural capacity.



CP-40 "Boyer" Hammer, top choice in shipyards, boiler works, etc.



CP Baby "Boyer" Superior. Mainly used for lighter constructional work within the $\frac{3}{16}$"—$\frac{1}{2}$" range.



CP-90 "Boyer" One of the 'heavies' in the range. A long stroke pattern to handle $1\frac{1}{4}$" hot rivets.

One firm needs a riveter for driving home $\frac{1}{16}$" Dural rivets, another for $1\frac{1}{4}$" hot steel rivets on heavy construction work, and in between this vast range of applications are demands for an amazing number of speeds, sizes, weights, lengths of stroke and types of handle. And for *all* these jobs — CP can supply the right tool.

CP in fact make the right riveters *for every* type of work — from shipbuilding to aircraft assembly Six of CP's wide choice of riveters are illustrated here; you can see the full range in the CP 24 page Riveting Tools Catalogue. Send for your copy.

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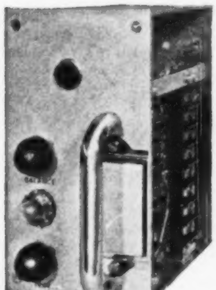

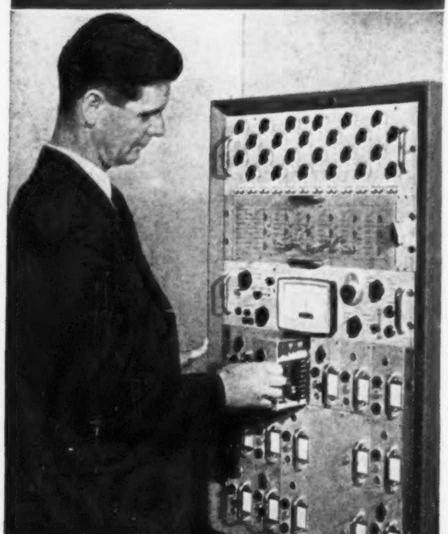

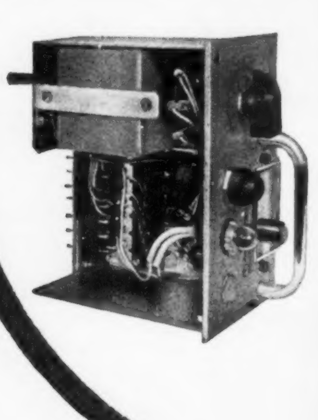

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From 1919 to 1960 the National Benzole Company has been bringing sleeping beauties to life – and not only the Princesses of Vintage-land. For Super National has a magic of its own that makes today's high-compression engines sit up and take notice. Super National, in fact, contains specially compact hydrocarbons called Benzole Aromatics. They fit together as neatly as a happy ending. Just one reason why Super National has such tremendous energy in every gallon. Result: fairy-tale performance, no knocking, more miles to the gallon. To wake your engine to full life, fill up with Super National, the high octane/high aromatic mixture. Next time you're out, turn in at a friendly National station.

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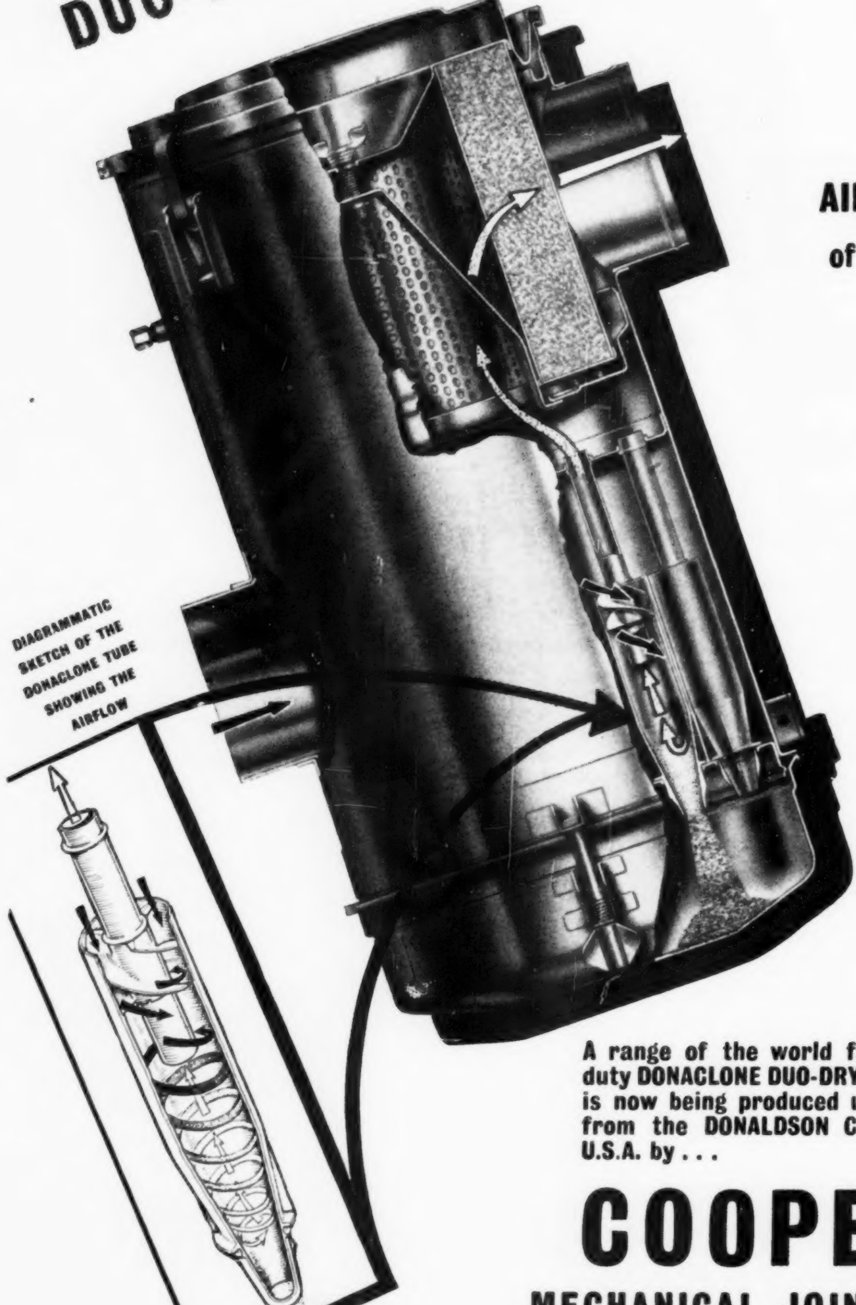

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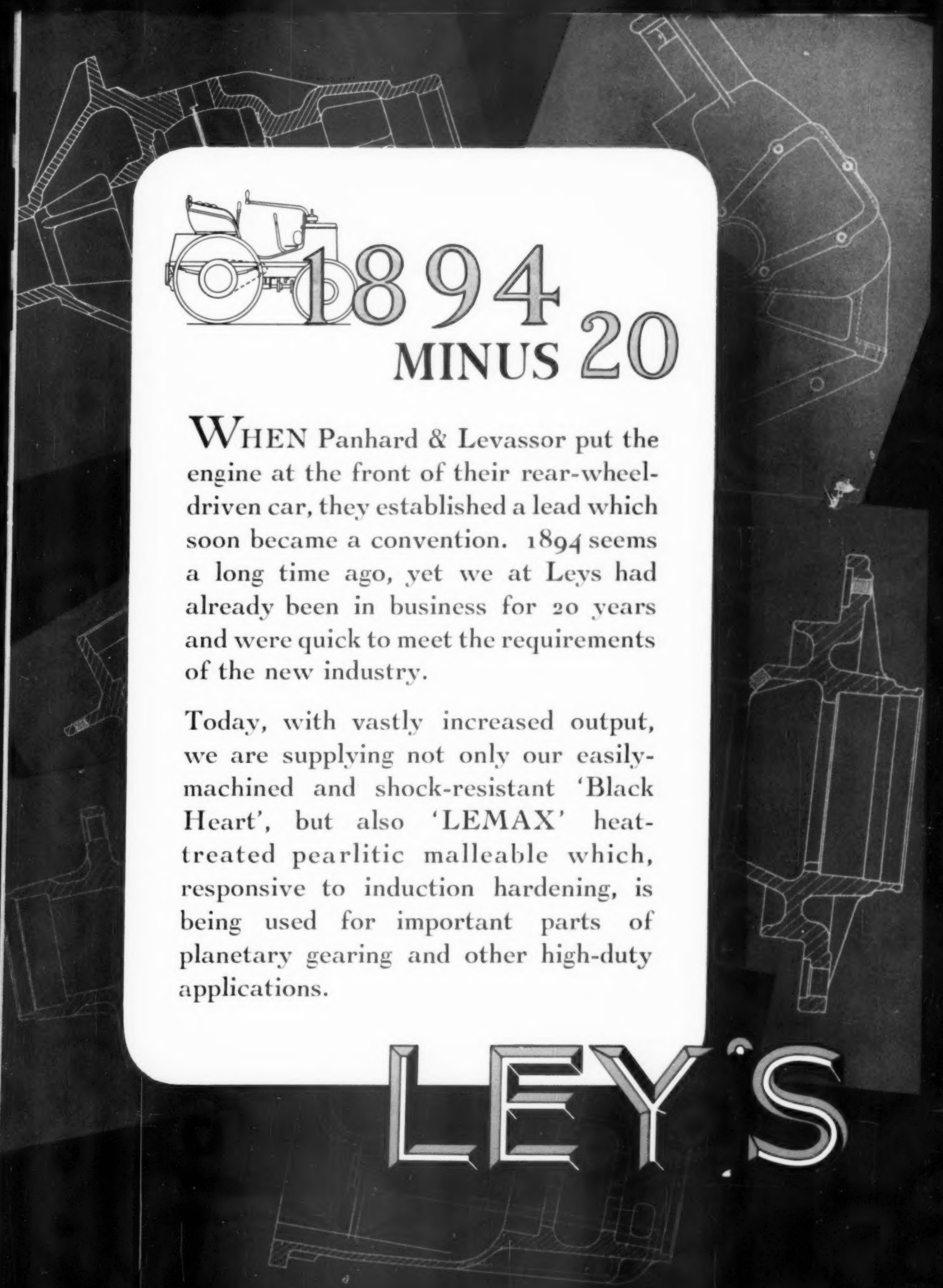
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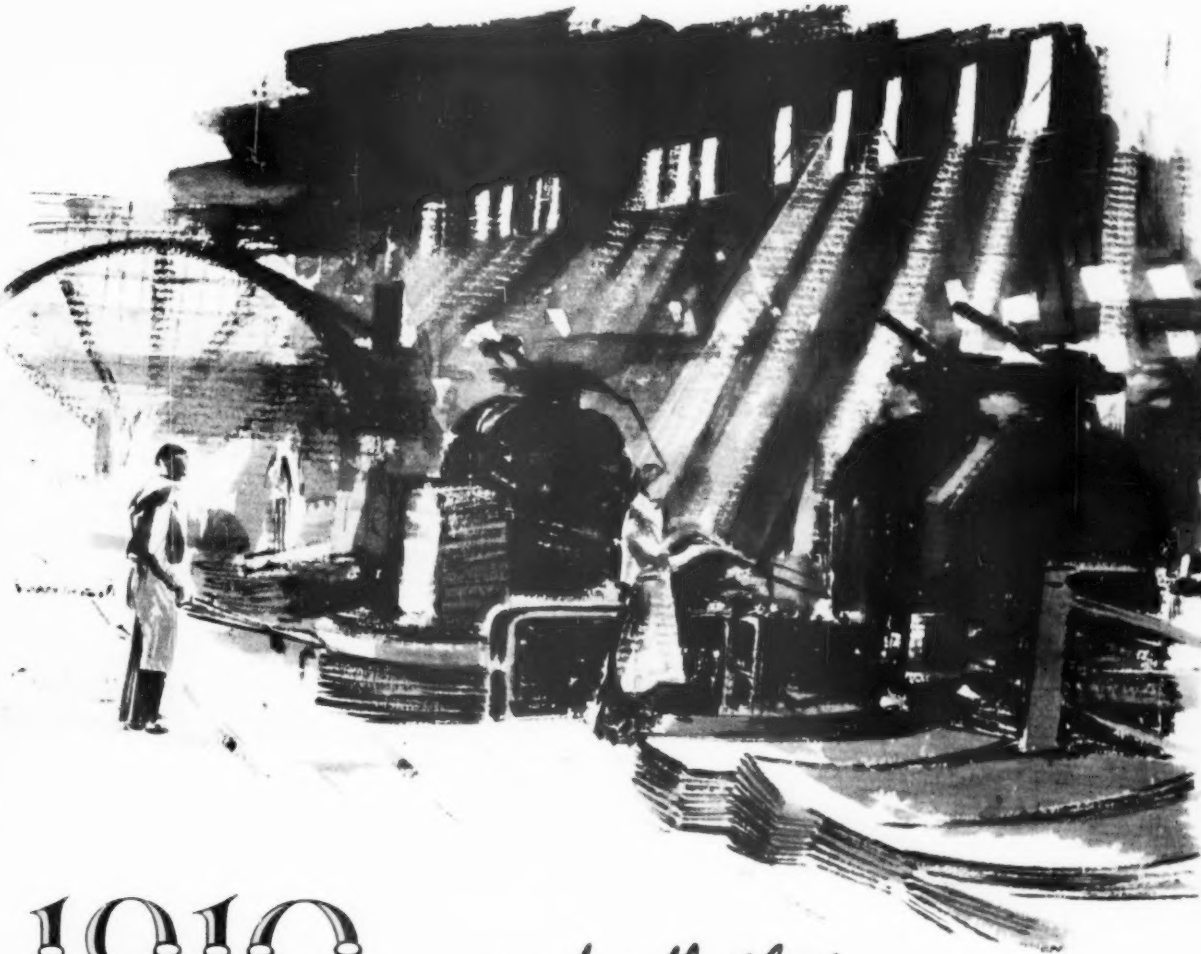

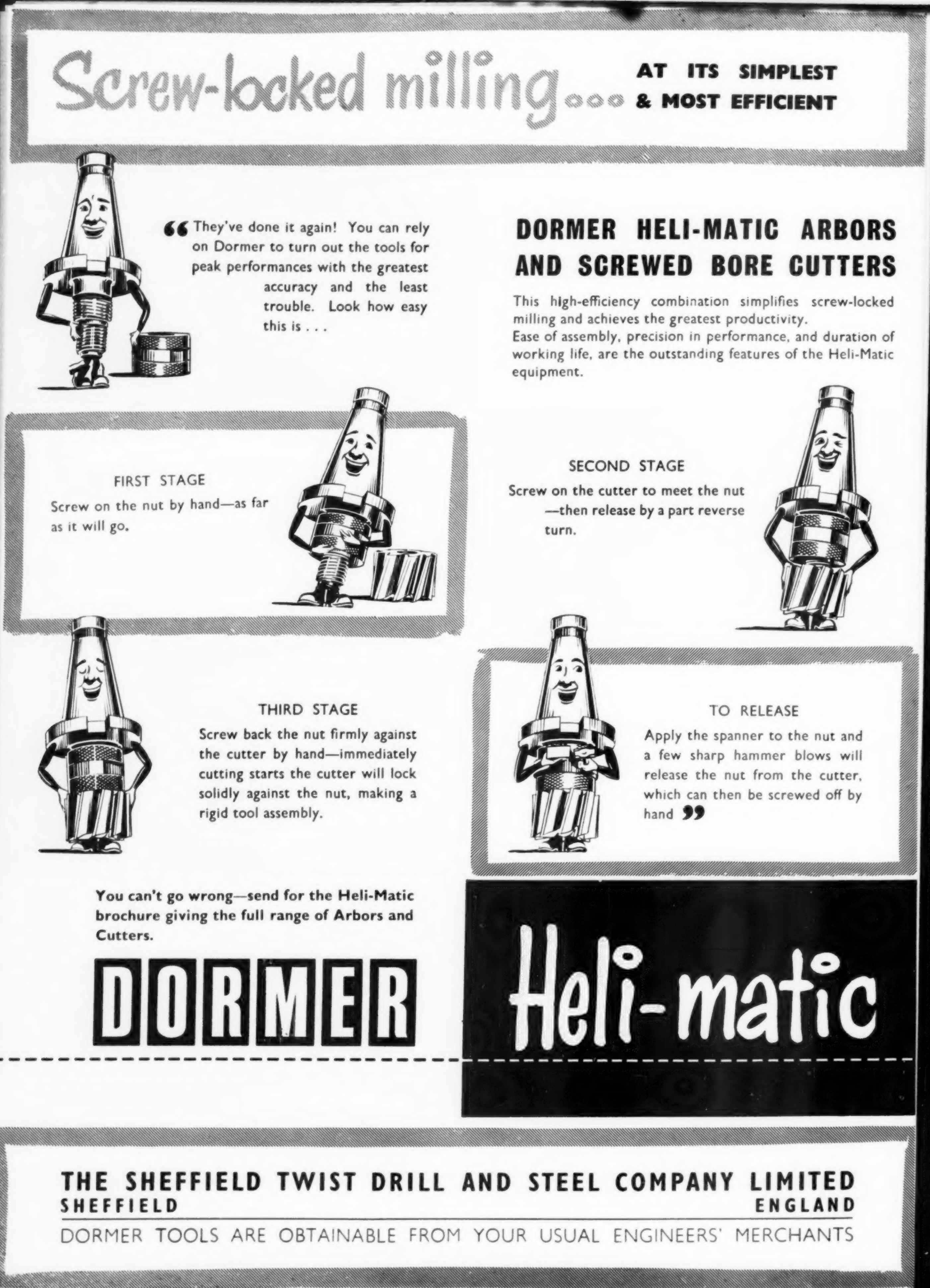

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Screw on the cutter to meet the nut—then release by a part reverse turn.
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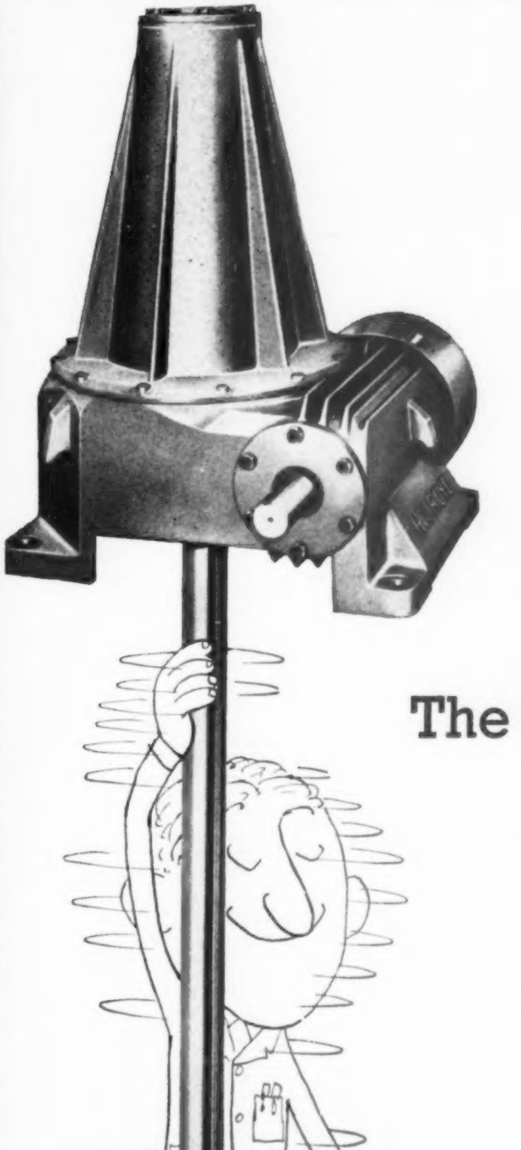

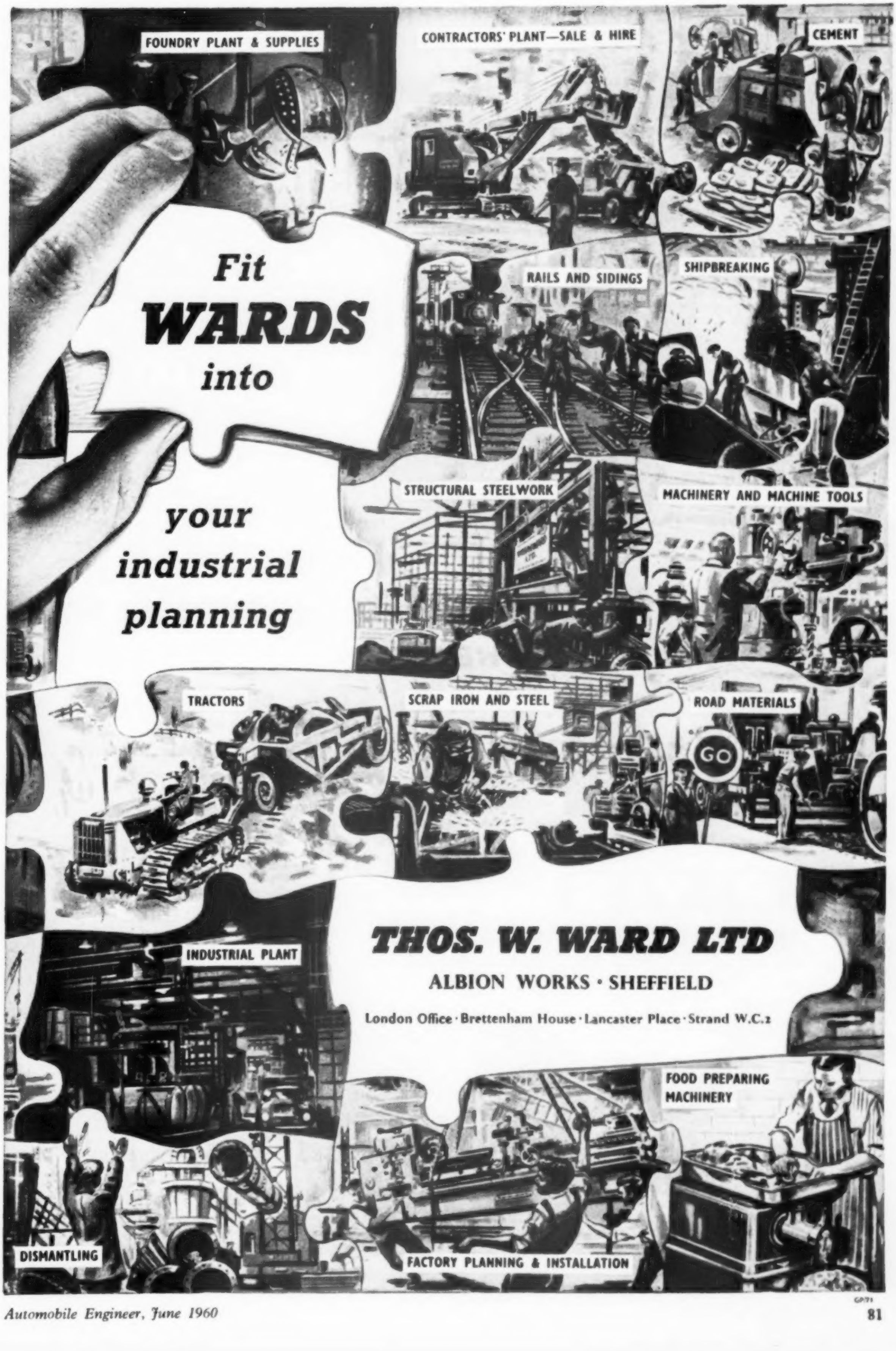
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Dielectric Heating-3

Some further details of the uses to which dielectric heating can be put are given in this data sheet, being continued from data sheet No. 11.

The Woodworking Industry

A most important development in recent years in the woodworking industry has been the introduction of synthetic resin adhesives of the thermosetting type for the bonding and adhesion of wooden components.

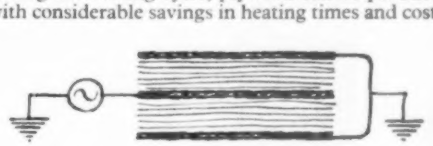
Setting of these resin adhesives proceeds at a rate largely determined by temperature. For instance, urea formaldehyde, one of the resins in common use, sets as follows:

TEMPERATURE	SETTING TIME
65°F	3 hours
80°F	1 hour
150°F	3 minutes
190°F	1 minute

The resultant bonded joint is equally satisfactory in each case. Most of the power supplied when dielectric heating is used is absorbed by the resin, the heat thus being concentrated where required and power consumption reduced to a minimum.

Plywood

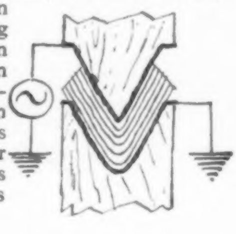
With dielectric heating consuming power only during the heating cycle, plywood can be produced with considerable savings in heating times and costs.



For example, in a press holding 100 3-ply ½" thick assemblies, the resin glue is set in 20 to 30 minutes, depending upon the dryness of the wood. An output of up to 60 cu. ft. of plywood is obtained per hour using a 25 kW H.F. generator.

Curved Laminated Sections

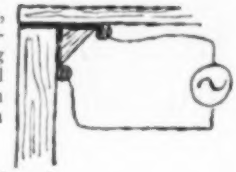
Curved laminated sections are being increasingly used in contemporary furniture, and with dielectric heating rapid production can be achieved using wooden shaping blocks in single daylight presses. An alternative method of providing heat by conduction from heated metal strips becomes increasingly slower as the total section thickness rises above 0.05 inch, as shown below:



TOTAL THICKNESS OF LAMINATIONS	*Comparative heating times in minutes* CONDUCTION	DIELECTRIC
1 inch	20	4
⅜ inch	5½	2½
0.6 mm veneer	1	1¼

Furniture Assembly

Because of the savings in glueing processes already instanced, dielectric heating is being extensively used in the furniture trade. It leads also to reductions in labour and floor space, with the elimination of assembly jigs. The heating equipment can be placed directly in the production line, cutting handling to a minimum.



Resin-bonded Wood Chipboard

A substitute for natural timber is made from wood waste and chippings, broken down to a coarse size, mixed with synthetic resin and heated under pressure. Dielectric heating gives quick and uniform heating, and increased fluidity reduces the power required for the final pressing and curing operation. In a continuous process, the length of the press required is also reduced.

Blockboard

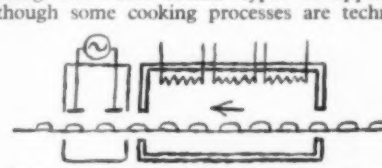
Production of blockboard by edge glueing strips of wood also provides an excellent use for dielectric heating, since considerable savings in time and labour can be effected owing to the large areas of glue line involved.

Other Resin-bonded Products

Dielectric heating is also used in the manufacture of other resin-bonded or impregnated products such as grinding wheels, impregnated woods, fabrics, felts, glass-fibre and similar products.

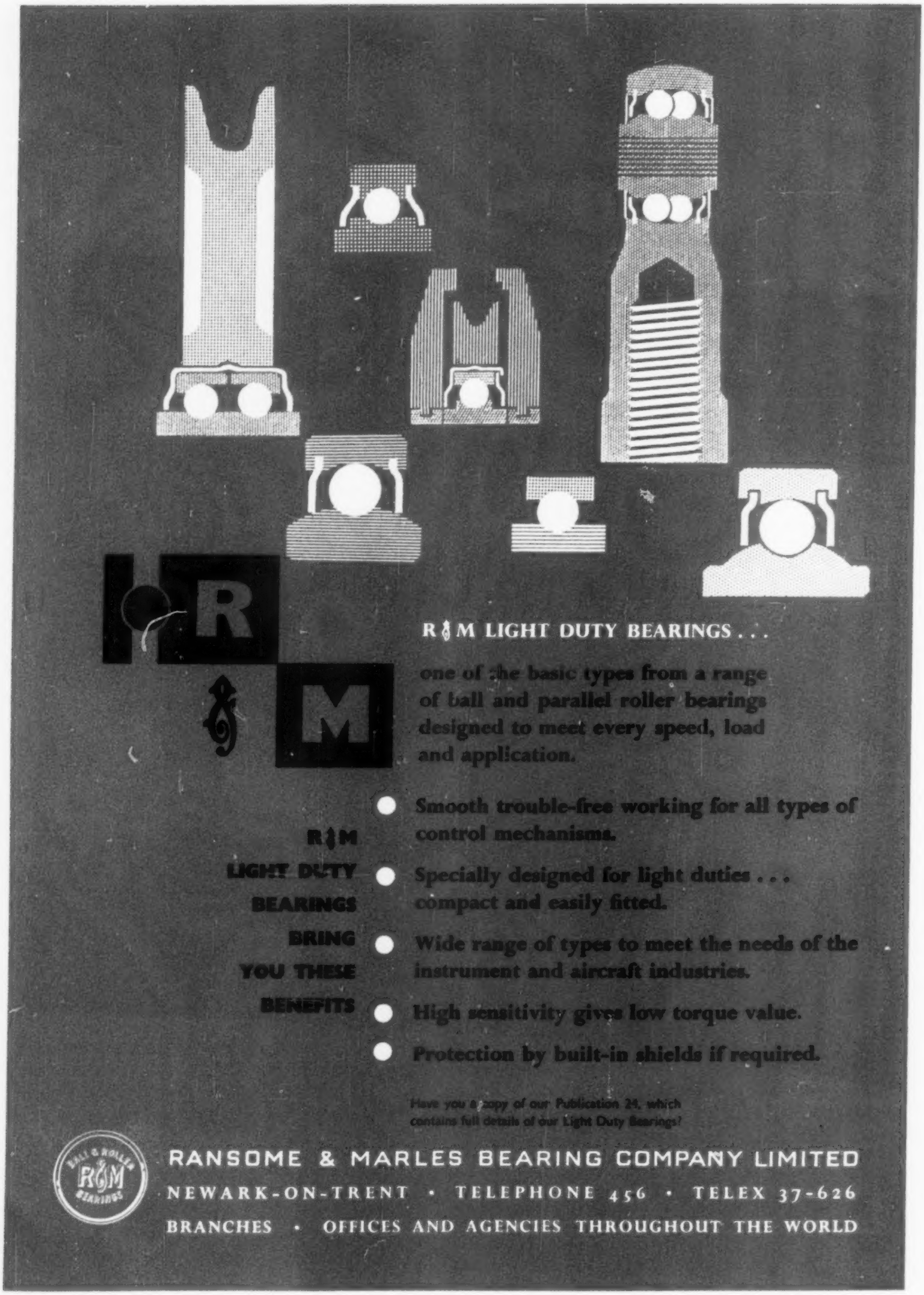
Foodstuffs

Increased use is being made of dielectric heating in many processes connected with foods; these include de-freezing and melting, sterilisation and disinfestation, drying of breakfast cereals, dog biscuits, rusks etc., heating of nuts to facilitate shelling and other similar types of application. Although some cooking processes are technically



possible, as for example bread baking, the 'unbrowned' product has so far proved unacceptable to the public and a completely dielectric process uneconomical. When combined with conventional baking, however, as now in the biscuit trade, where dielectric heating is being used to complete the baking of biscuits, it can produce normal biscuits in ⅓ to ½ the usual baking time.

There are in fact so many potential applications of dielectric heating (and these applications are increasing daily as the chemical industry develops new products, as for example synthetic fibres) that the selection given in the present series of data sheets covers only a part of the whole field.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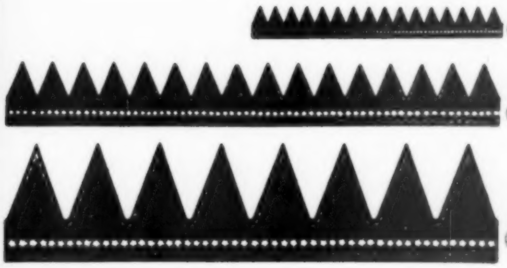

(J)
(L)
(M)

THERE ARE THREE BASIC RIB SIZES OF POLY-V BELT

Section	Rib Width	Rib Quantities	
		Minimum	Maximum
J	$\frac{3}{32}$ in.	2	16
L	$\frac{3}{16}$ in.	6	20
M	$\frac{3}{8}$ in.	4	20

V angle is 40 in each case.

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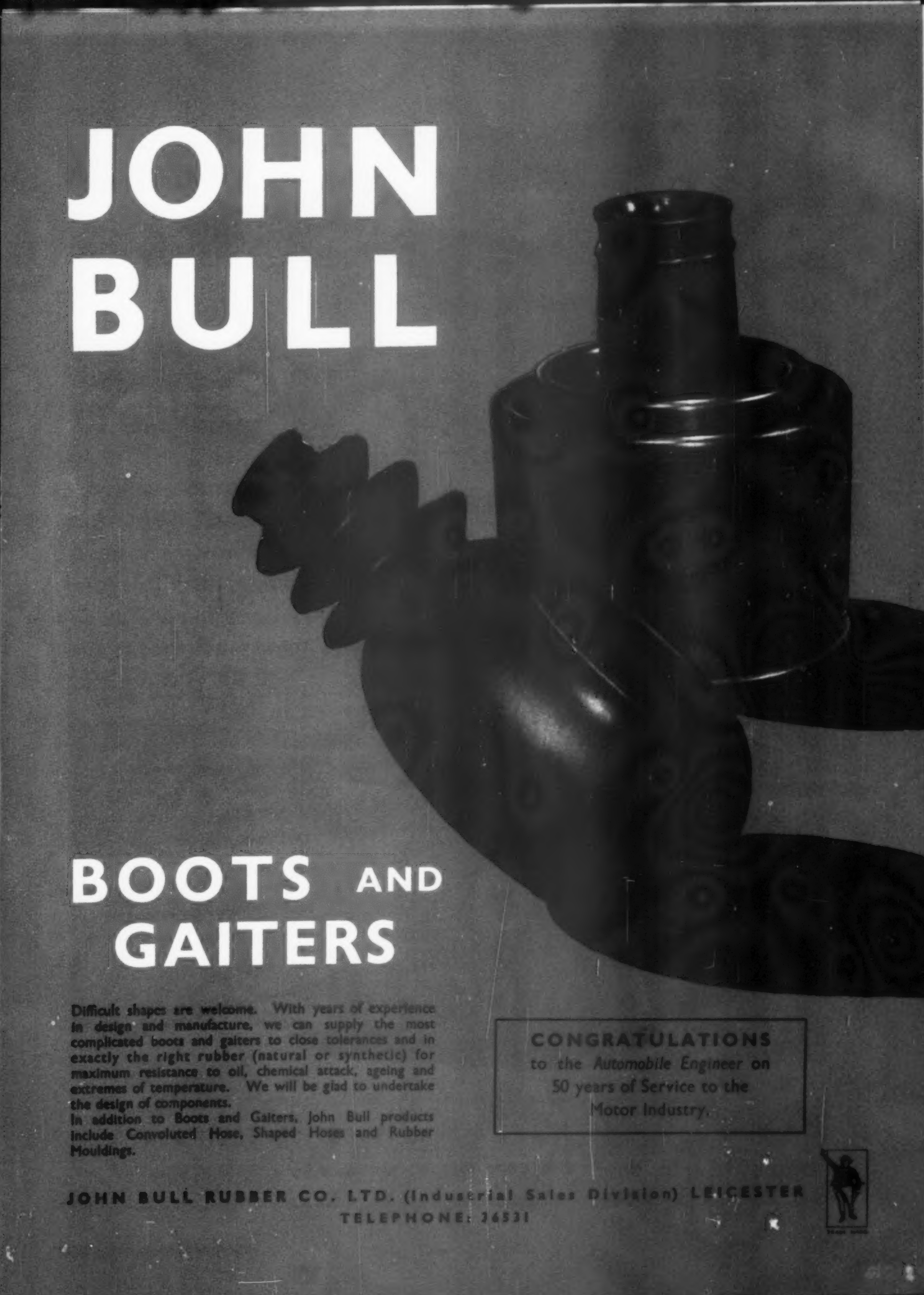
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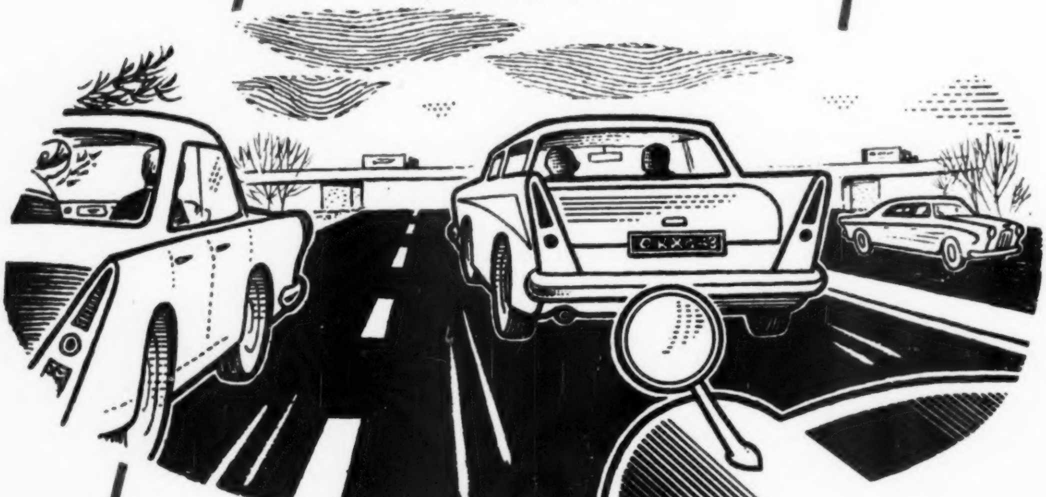
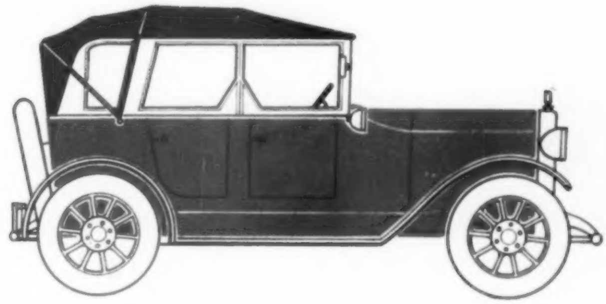


MORRIS

MG



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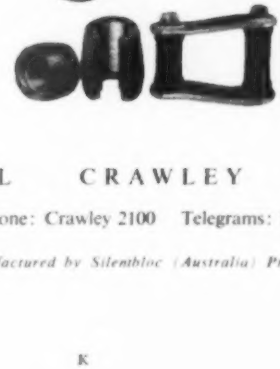

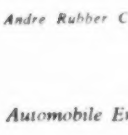

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655,299 36,674/55
700,254 36,675/55
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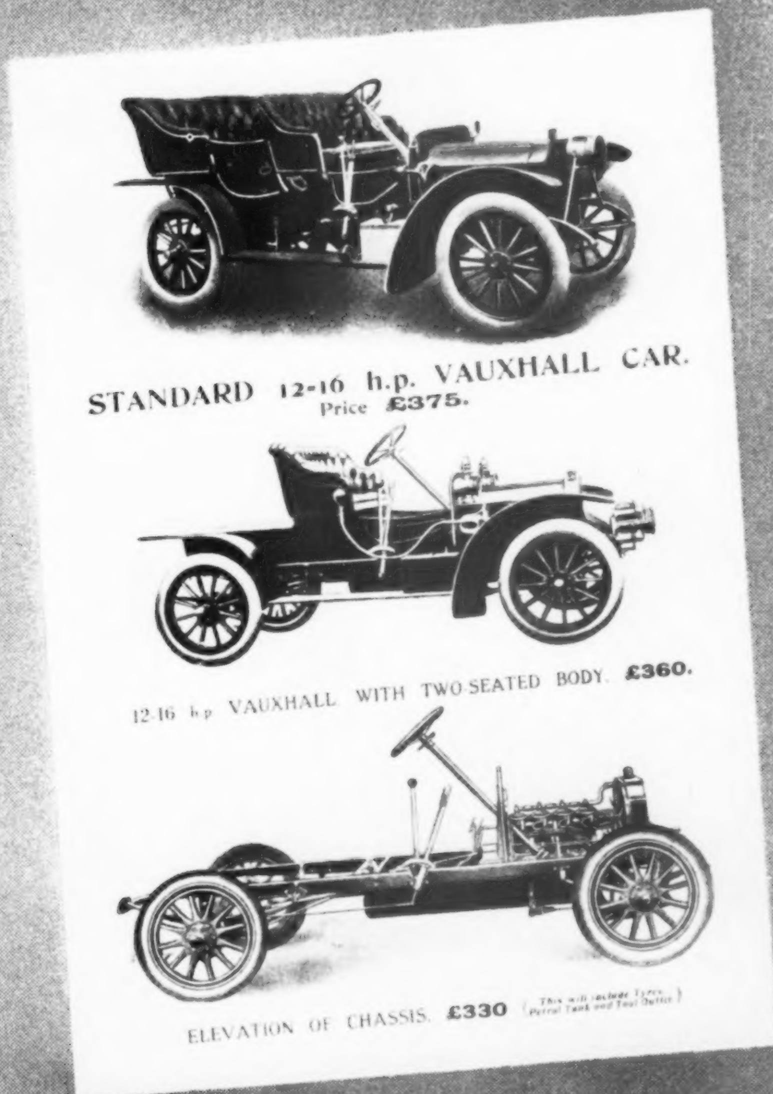

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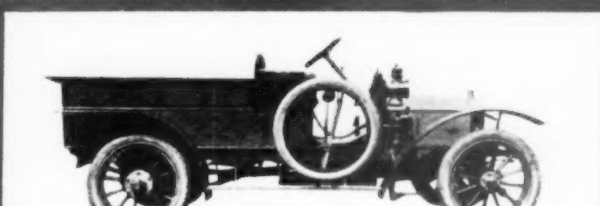

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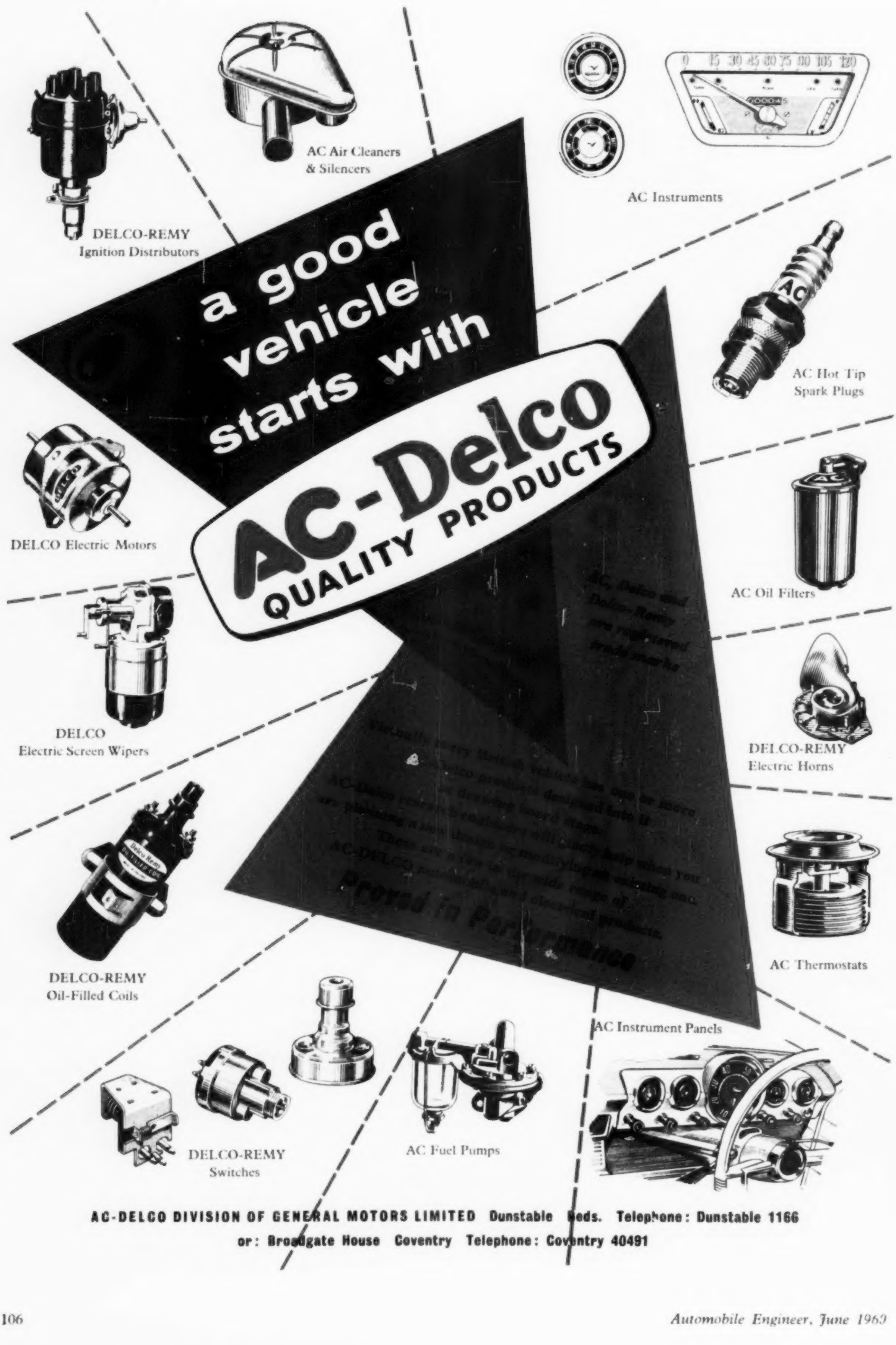
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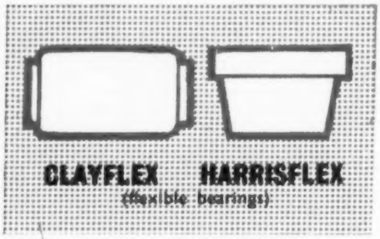

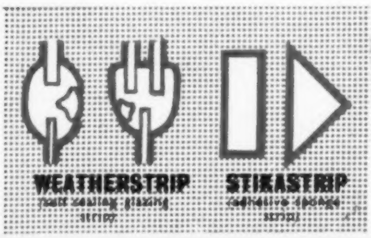

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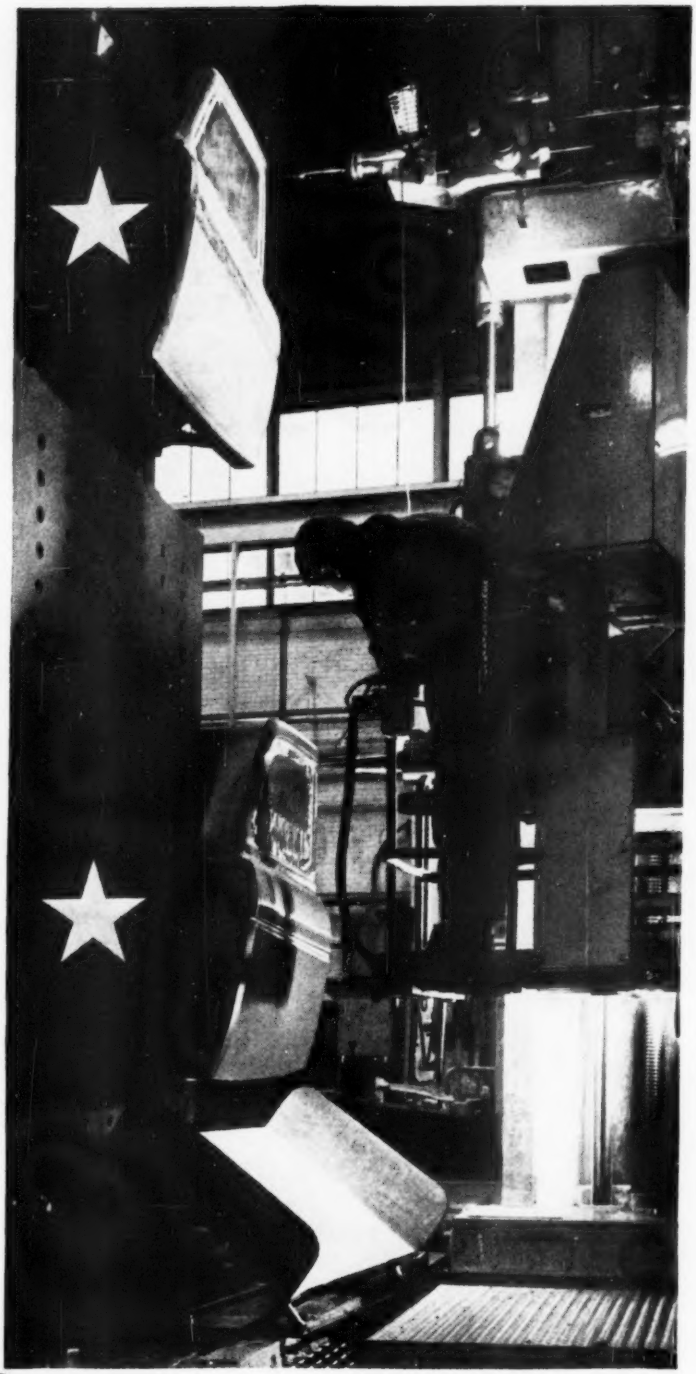


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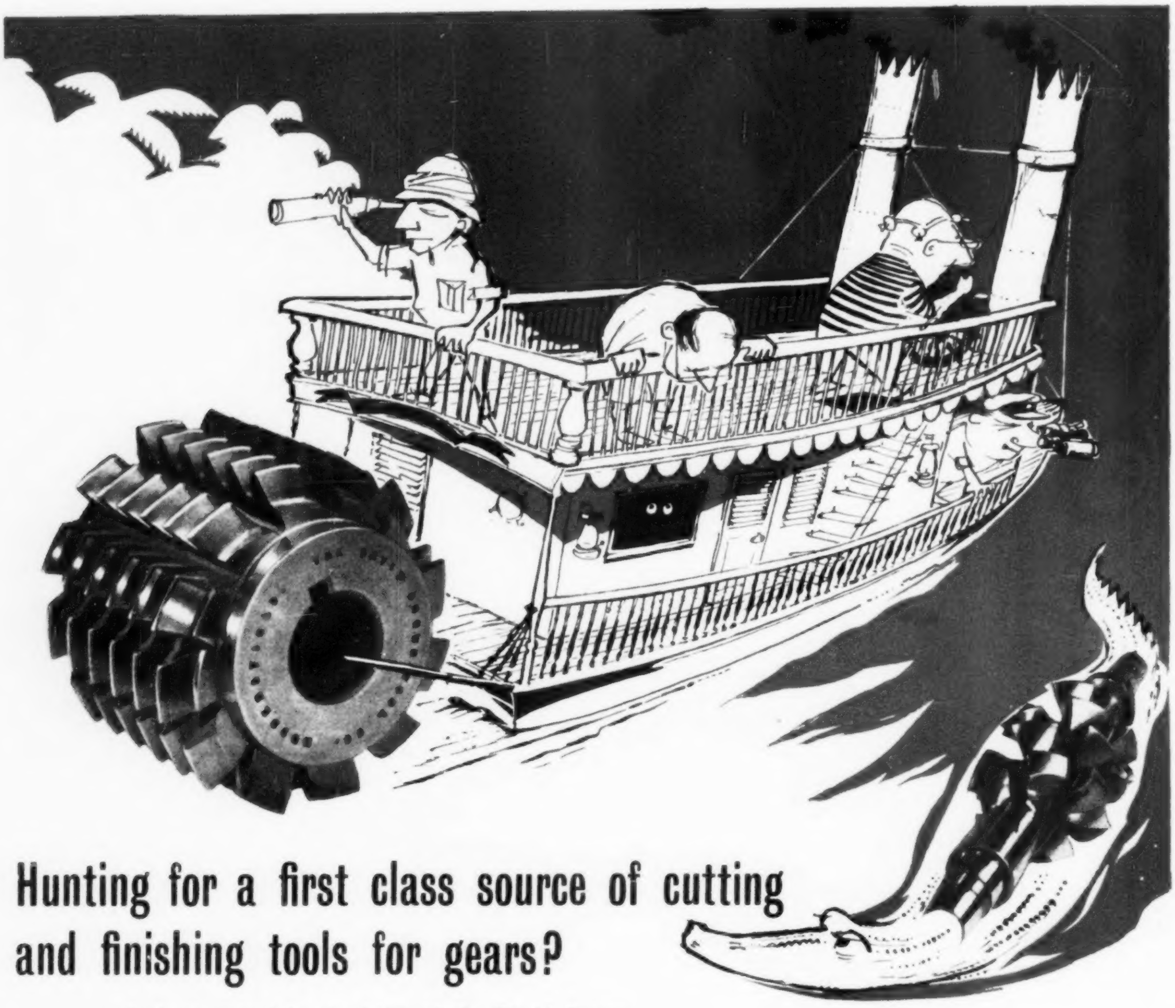

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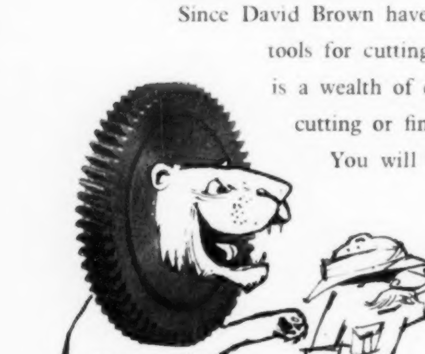

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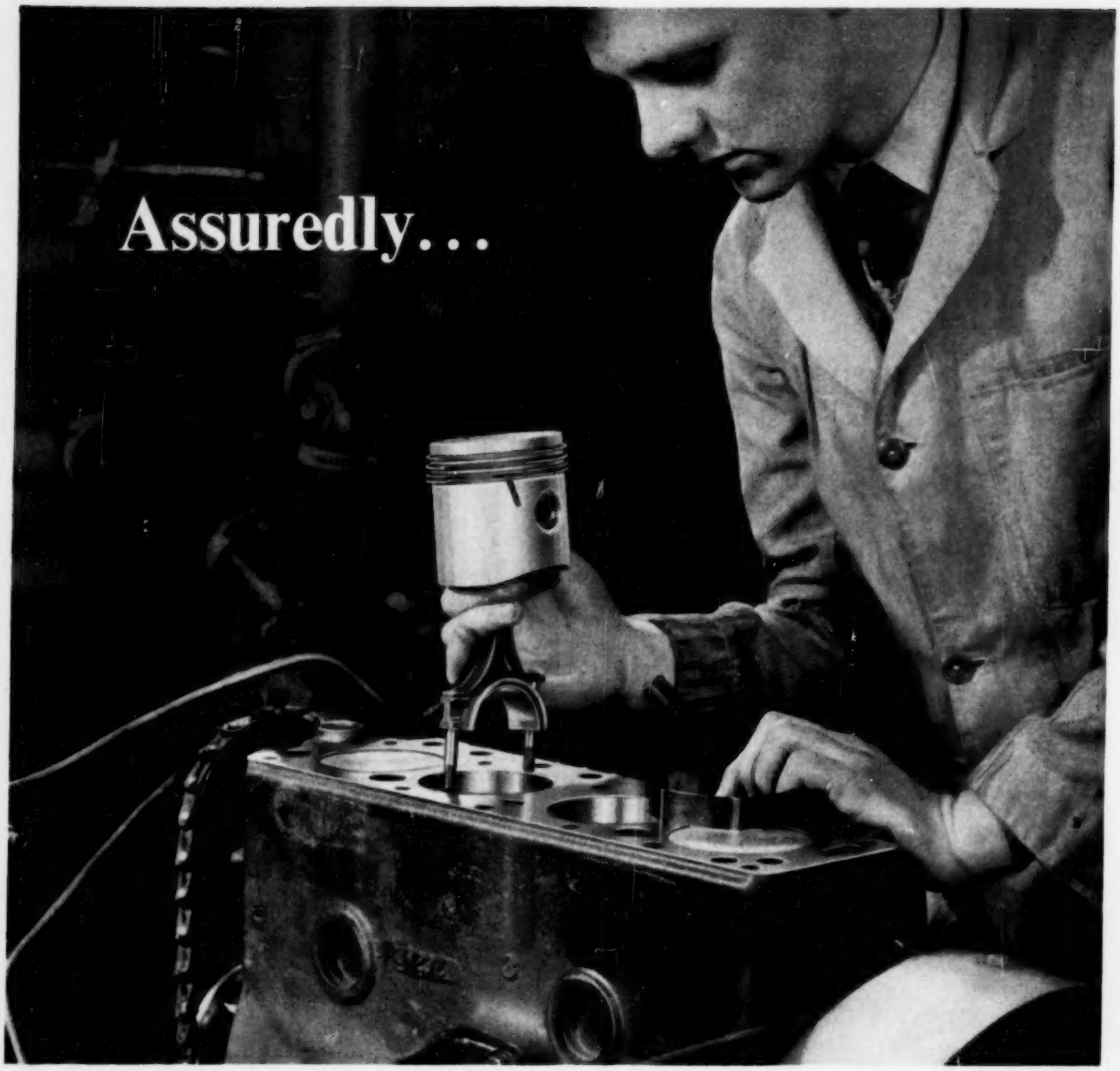

This is the last in a series of advertisements describing some of the factors which combine to give Hepolite products their superior qualities. The picture shows an experimental piston being fitted to a test bed engine.

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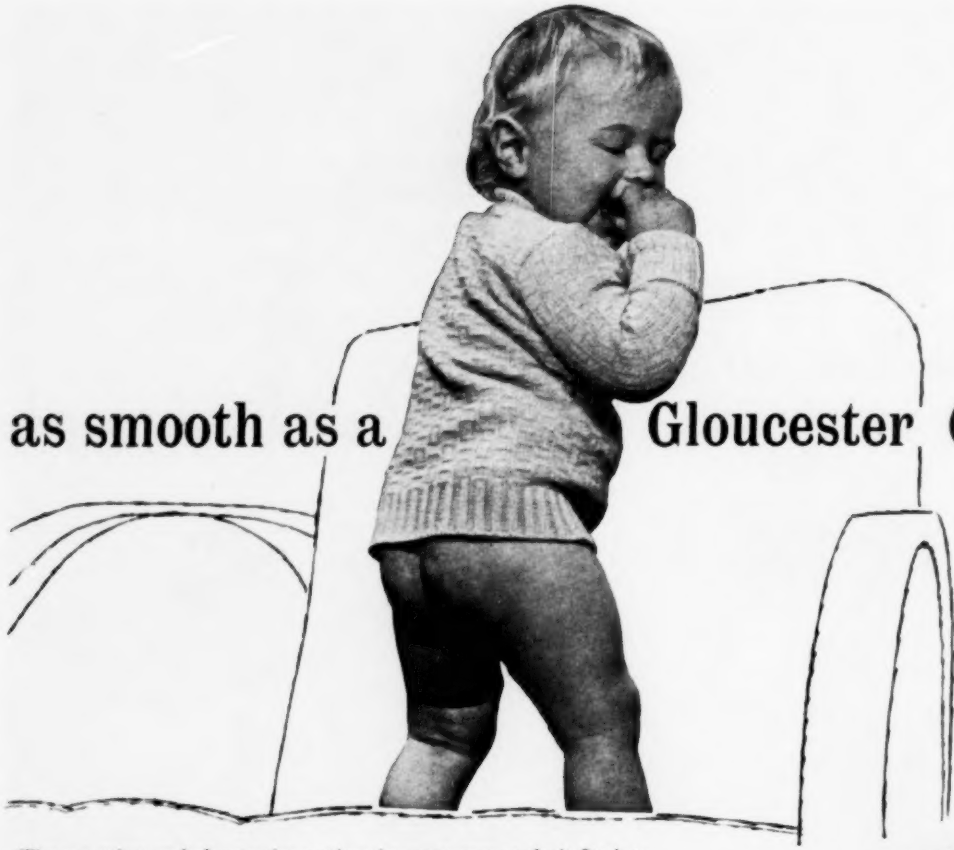

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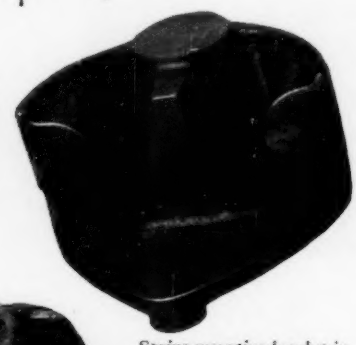

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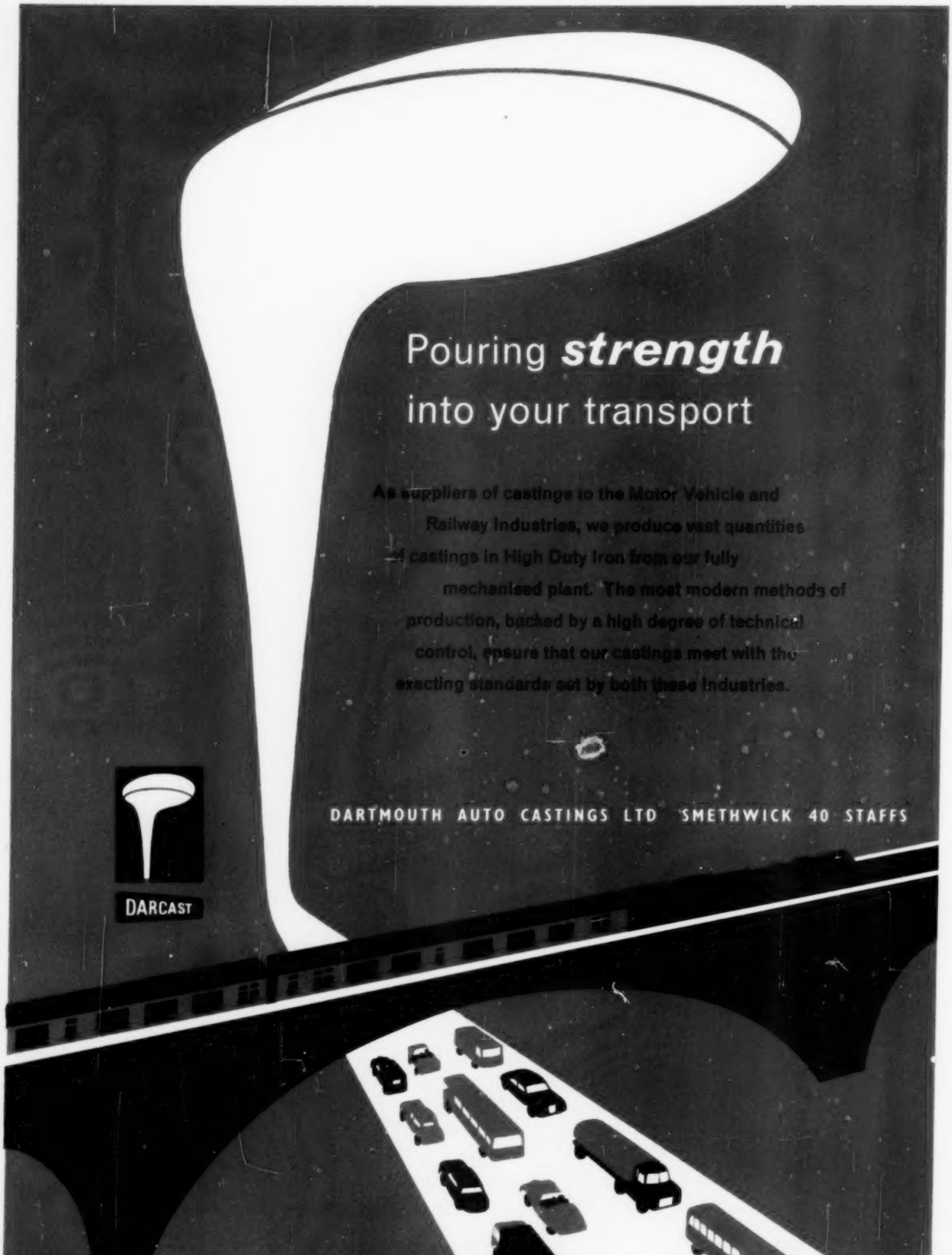
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AUTOMOBILE ENGINEER

THIS HANDSOME AUSTIN TAXICAB, CONCEIVED IN 1910, DEMONSTRATES PLAINLY THAT THE ART AND SCIENCE OF MOTOR VEHICLE DESIGN WAS WELL ADVANCED BY THAT DATE

CONTENTS

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Editorial Staff *F. C. Sheffield (Associate Editor)*
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DESIGN MATERIALS **AUTOMOBILE ENGINEER** PRODUCTION METHODS WORKS EQUIPMENT

The Industry and the Journal

ON this the occasion of our Jubilee we will be forgiven for writing about ourselves and our relationship with the automobile industry. The *Automobile Engineer* was first issued in June 1910 by our publishers, Iliffe and Sons Ltd. At first, it was a monthly journal, but after eighteen months its name was changed to *Internal Combustion Engineering* and at the same time it became a fortnightly publication. Although it still dealt with the design and production of motor vehicles, its field was extended to cover gas and oil engines for industrial and marine applications. Then, as a result of the rapid growth of the automobile industry, it was later decided that, in January 1914, the journal should be split into two, re-establishing the *Automobile Engineer* and forming a separate journal called *Internal Combustion Engineering;* both were monthly publications.

From the year 1919 to 1932, the *Automobile Engineer* was the official organ of the Institution of Automobile Engineers and, through its associated journal *Engineering Production,* which was first published in 1920, was indirectly concerned with the start of the Institution of Production Engineers—the editor of *Automobile Engineer* at that time was also responsible for *Engineering Production.* Then, in May 1925, these two journals merged. In September 1931, the *Automobile Engineer* incorporated another journal, *Motor Body Building,* which had evolved from a publication that had started in 1880, when the horse-drawn vehicle was unchallenged on the road.

The history of this latter journal is of interest. It was originally *The Coachbuilders, Saddlers and Harness Makers Art Journal;* in 1898 it was changed to *The Coachbuilders and Wheelwrights Journal;* then, in 1902, with the advent of the automobile, the three words *Motor Car Manufacturers* were incorporated in the title. In 1910 this long title was dropped and the publication was called *Coopers Vehicle Journal,* after the name of its founder, and in 1923 it became *Motor Body Building.*

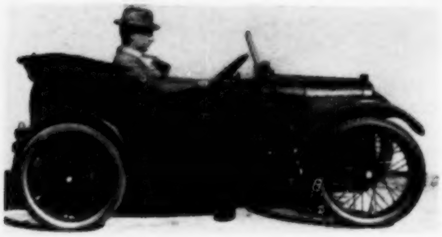
The leading article in our first issue, in June 1910, stated that "Although there is a plentitude of journals devoted to the interests of motorists, not one of them can devote full attention to purely technical matters". It goes on to the effect that we are confident therefore that we shall procure the support of all those to whom the theory and practice of automobile engineering are of interest and importance, not only in Great Britain but also throughout the world. In short, the aim was at supporting the industry in its constant struggle to improve both design and production.

That has been our aim throughout the whole of our fifty years of publication, and we cannot see any likelihood of its being changed; but since perfection is unattainable in any sphere, we also do not foresee any prospect of our ever being really satisfied with our attainments. We can, however, continue to be of considerable help to the industry in many ways. For example, because of our position, at a convenient distance from the harrowing day-to-day problems that take up so much of the time and attention of engineers within the industry, and therefore our facility for obtaining an overall picture, we have a unique opportunity for assessing the merits of, for example, details of design relative to the broader aspects of other developments within the industry.

Another way in which we can and do help the industry is by placing on record experience gained in research and development by individuals within the industry. In this connection, it is not always adequately appreciated, by those who might contribute articles, that even though a research or development project yields a negative result, and therefore nothing emerges that can be applied to a production vehicle, it can be of great interest and value to all engineers. A good example of this is the article on differential drives for superchargers, which was published in our September 1955 issue.

Although most of our articles are devoted to subjects of current interest, we regard forward thinking as of utmost importance. Assessments of the probable trends of future development are, of course, essential to those who are responsible for overall planning: hence we have always regularly published articles of this type. Because of the ever increasing complexity of the industrial scene, however, and the vast capital investments at stake, it is becoming necessary to plan even further ahead than ever before, on a basis of all existing and foreseen factors likely to influence the course of development.

In general, the first part of the current issue is devoted to historical reviews, which we hope will prove of absorbing interest not only to those who have played an active part in the evolution of the motor industry but also to younger engineers who wish to know more about the genesis of design and production. We have had to devote this section almost entirely to the British industry, for the simple reason that to cover developments throughout the whole world would require a prohibitive amount of space. However, we should like to take this opportunity to pay a tribute to the vast contributions to progress that have been made by other great motor manufacturing countries such as France, Germany, Italy and the United States of America. For those of our readers who are not so interested in history, a large part of the space in this enlarged number is devoted to technical articles of current interest to design, research and production engineers.



The 1922 Austin 7 with Lord Austin at the wheel

BEGINNINGS

Sagas of the Pioneers of the British Firms that Started Building Cars Before 1910 and also of those that are Currently in Production on a Large Scale

THE history of the motor-car industry is perhaps one of the most interesting stories of industrial development that can be told. Most of the firms still in existence started in a very small way, some manufacturing and some merely selling and servicing engineering equipment such as bicycles and even products unrelated to mechanical transportation. Of the many firms that have fallen by the wayside in the face of fierce competition and industrial recession, the memory of only a few is kept alive by the retention of their names for some of the products of the large groups of manufacturers that have absorbed them.

In most instances, the stories are of one man, or of a very small group of men, whose untiring efforts and tenacity of purpose carried their organizations through the very hard times that almost inevitably befall tiny firms when they first start business. And then, as the firms have expanded and have relied on teamwork for their great accomplishments, it has always been the personalities of a very small group of men right at the top that has determined the character and therefore to a large extent the success of the business. In fact it is a sobering thought, for those who today lead industry, that what they see, good or bad, when they view their own firms, is in all probability a reflection of themselves.

AC Cars

The founders of AC Cars Ltd., Mr. Weller and Mr. Portwine, were in association before 1900; in fact, by that year Mr. Weller, who was the mechanical genius of the two, had already built his first car. In 1904, a new firm, Autocar and Accessories Ltd. was formed, and it started making a very light, three-wheel commercial vehicle called the Auto-Carrier. Then in 1907 the firm was re-named Auto-Carriers Ltd., and work began on the AC Tricar. This vehicle was similar to the Auto-Carrier, with two wheels at the front, but fitted in place of the 3 cwt capacity box above these wheels was a seat to carry two people. In the same year, the name of the firm began to be abbreviated to AC.

Originally the factory was at West Norwood, but in 1911 it was moved to Thames Ditton, on its present site. By 1913 Weller had designed a four-wheel car, but because of the outbreak of the war it was never produced; however, by 1919 a six-cylinder overhead camshaft engine was running on test. In 1921, S. F. Edge, famous in connection with Napier, joined the board of directors, on the resignation of Portwine and Weller, and the company ventured with great success into the competition field. In 1929, the company went into voluntary liquidation, only its service department remaining open. However, the company was re-formed, by W. A. E. and C. F. Hurlock, in 1930.

Alvis

It is said that the name Alvis was chosen because the initial letter A would give it precedence in respect of treatment in the press and other literature such as motor show catalogues. The reason for the choice of the other letters is obscure, but it is thought to have been taken from the name Avis, with the L added to fit it into the triangular motif for the front of the radiator. Initially this motif was similar to that of A. V. Roe and Co. Ltd. but, after a legal action, the Alvis triangle had to be inverted and the colour of it changed from a blue shade to the red that we know today.

Armstrong Siddeley 30 h.p. car which, in 1922, gained a Certificate of Performance for successfully completing the R.A.C. 15,000 mile reliability trial

OF AN INDUSTRY

This wonderful pioneer is the 1911 model T Ford

In 1909 the first 7 h.p. Austin car was produced

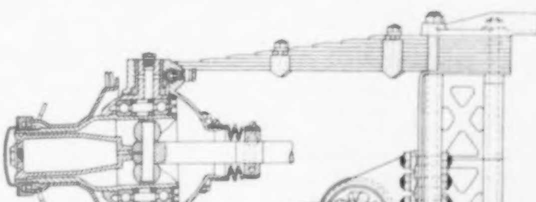
The firm was started in Coventry in 1919 by T. G. John. At that time it was called T. G. John Ltd. and was simply a foundry for the production of light alloy castings. Its field of activity was almost immediately enlarged by the production of a motor-scooter and the Buckingham stationary engine, and in 1920 T. G. John became interested in the production of cars. The first model produced was the 10/30 h.p. vehicle, which they believe to have been designed by an engineer called de Freval who had previously been concerned with the beginning of the Bentley organization—as has happened with several Coventry manufacturers, records were destroyed by bombing during the last war.

B.M.C.

Although the first Austin-designed car was shown at the Crystal Palace Exhibition in 1896, it was actually made by the Wolseley organization. Originally, in 1887, the Wolseley Sheep-Shearing Co. Ltd. was established in Sydney, Australia, for the purpose of exploiting patents held by F. Y. Wolseley. By the time the English company was established, in 1889, that in Australia had been wound up. The association between Herbert Austin and F. Y. Wolseley began in Australia, where Mr. Austin had gone in 1884 to work in an engineering firm, of which his uncle was the manager; and as a result of the impression he made, he was offered in 1893 the position of manager of the Wolseley Sheep-Shearing Machine Co, just off Broad Street, Birmingham.

In 1895 a department was opened for the manufacture of machine tools, principally for cotton machine makers. At the same time, fairly large quantities of bicycle parts were being turned out and even complete bicycles. So far as the production of motor cars was concerned, Herbert Austin had no support from his directors, who would not agree to any money being wasted on what they held to be a pointless venture. Consequently, the first Wolseley car, a tiller steered three-wheeler, was made in secret in 1895, largely in Herbert Austin's spare time. Experiments continued and in 1900 a four-wheeled vehicle, with a horizontal, single-cylinder engine, was built and won first prize in the Automobile Club of Great Britain 1,000 Mile Trial. The following year, 1901, the Wolseley Sheep-Shearing Machine Co., with Vickers backing, set up the Wolseley Tool and Motor Car Co. at Adderley Park, Birmingham. In 1904, when the firm joined forces with the Siddeley Autocar Co., the name was changed to the Wolseley Tool and Autocar Co.

Herbert Austin was manager of the Adderley Park factory, but in the early summer of 1905, after a dispute with the directors, he resigned and started on his own in a small derelict works that had previously been used by the firm of White and Pike Ltd., for the manufacture of metal boxes. Thus began the Austin Motor Co. Ltd. In 1905, Herbert Austin and his two draughtsmen, A. J. Hancock and A. G. Davidge, took blueprints to the Motor Show at Olympia, sought orders for the first Austin car and got them. In the first full year of production 270 workmen turned out 120 cars. By 1910, 1,000 workers were employed, and a night shift was undertaken. A single-cylinder 7 h.p. car and a 15 h.p. town carriage were added to a range that now included 10, 18-24, 40 and 50 h.p. models and a 15-cwt van. The production of a 2/3-ton lorry in 1913 marked an excursion into yet another field.



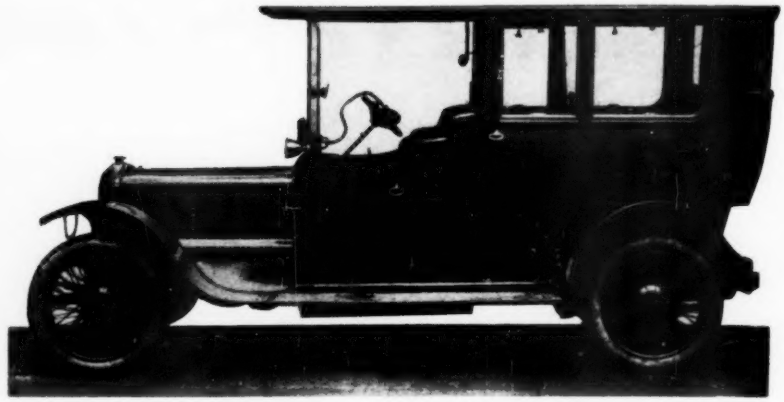
The front wheel drive and suspension layout on the 1926 Alvis model

After an impressive contribution to World War I, the factory was employing 22,000 persons and producing 200 cars per week. It is of interest to compare this with the current output of the Longbridge works, where approximately the same number of people is employed but, in a record week, 7,000 units have been produced. Although admittedly some of these were in the c.k.d. condition, the increase in productivity per person employed that this represents is nevertheless impressive.

The Austin Motor Co. came upon difficult times in the slump that followed two or three years after World War I, but the introduction of the 7 h.p. car, the basic design of

which was retained throughout the years from 1922 to 1938, put the firm on its feet again, and since then it has never looked back.

When Herbert Austin started his new company in 1905, William R. Morris had been running his own firm for some twelve years, building bicycles and subsequently motor cycles. But it was not until 1910 that he started work on the design of his first Morris Oxford car, which was announced at the 1912 Motor Show at Olympia. For the production of these cars, a company called W.R.M. Motors Ltd. was formed in 1912. Mr. W. R. Morris was managing director of the company and held all the ordinary shares, except a few that were subscribed to by a close personal friend. The engine and gearbox of the first Morris Oxford were made by White and Poppe, of Coventry, the axles were made by E. G. Wrigley and Co. and the body was supplied by an Oxford coachbuilder.



Daimler 38 h.p. Langford limousine, of 1910-11, with shock absorbing rear spring shackles

In July 1919, after making a considerable contribution to the war effort, W.R.M. Motors Ltd. went into liquidation and a successor company, Morris Motors Ltd., was incorporated to take over the assets. By July 1920, sales of the new 11·9 h.p. Oxford and Cowley models reached a record of 280 cars per month. Then came the slump, and in the month of January of the next year only 74 cars were sold.

However, this setback was overcome, and in 1923 Morris purchased the Hotchkiss factory, so that he could be assured of a supply of engines and gearboxes—he had already acquired a radiator manufacturing company at Oxford and a body works at Coventry. By 1939 the extended Hotchkiss factory had a capacity of 4,000 engines per week, and the output from the Cowley factory was 120,000 per annum.

Towards the end of 1923 the assets of E. G. Wrigley and Co. were purchased and their factory turned over to the production of trucks and commercial vehicles, a new firm called Morris Commercial Cars Ltd. having been formed. Later, new premises were acquired at Adderley Park and the entire business transferred there.

Other businesses that were acquired by W. R. Morris are Hollick and Pratt, now Morris Motors Ltd., Bodies Branch; Osberton Radiators, now Morris Motors Ltd., Radiators Branch; and the S.U. Carburetter Co. Ltd. All of these were taken over in 1926. In 1927 Wolseley Motors Ltd. became part of the Morris organization, and in 1938 Riley Motors Ltd. also joined it. The last-mentioned firm was originally the Riley Cycle Co., founded by the Riley family, of Coventry, in 1896. As early as 1898, Percy Riley designed and built his first car.

We are now left with the M.G. Car Co. Ltd. not so far mentioned. W. R. Morris leased the premises of the Morris Garages, Longwall Street, Oxford, in 1903—although not until 2nd July 1927 was the business registered as a limited company. Cecil Kimber was appointed manager in 1922, and in the ensuing years was responsible not only for retail sales and service, but also for many different types of special bodywork on the standard Morris chassis. One popular body was the Chummy, an occasional four-seater; a similar type of body was produced in 1923 by Morris Motors at Cowley.

What Kimber himself regarded as the first M.G. was a much more sporting device. This was FC.7900, which had the scantiest of two-seater bodywork on a special chassis fitted with a Hotchkiss 11·9 h.p. overhead valve engine, of the type built for Gilchrist Cars in Scotland. Work on this car probably began some time in 1924; it was definitely first registered on 27th March 1925, and made its first appearance in the London-Land's End Trial held at Easter that year, when Kimber won a gold medal with it.

During these early years the demand for sporting bodywork of this type increased steadily, and several moves were made in search of more space for production. A small depot in Alfred Lane—now Pusey Lane—was used about 1923-26. Then, early in 1926, a move was made to Bainton Road—now Morris Motors Radiator Branch—and, during 1927, additional premises were taken in Merton Street and Leopold Street. But still there was insufficient space to cope with the rising demand and, late in 1927, a move was made to a new and much larger factory at Edmund Road, Cowley. The company was then known as The M.G. Car Company (Proprietors, The Morris Garages). Finally, late in 1929 the M.G. Car Company Ltd. was formed and moved to Abingdon. It is there that all B.M.C. sports car production is concentrated today, the weekly output being some 1,250 M.G. and Austin-Healey sports cars.

One of the most momentous events in the history of the British automobile industry was the Austin-Morris merger, which in 1952 led to the creation of the British Motor Corporation Ltd. The following year Fisher and Ludlow Ltd. was acquired, to secure a reliable source of supply for a proportion of the bodies required for the Corporation; the remainder are obtained from Nuffield Metal Products Ltd. and the Pressed Steel Co. Ltd. Of these three companies, the last-mentioned is of course independent. In general, bodies assembled and finished for cars manufactured at Cowley are obtained from the Pressed Steel Co. Ltd., while those used at Longbridge come from Fisher and Ludlow Ltd. and The Austin Motor Company's own body works at Longbridge; currently the Morris Minor body is still made at Nuffield Metal Products' factory in Birmingham.

Bristol Siddeley

Next in alphabetical order on the list of motor manufacturers still in production is Bristol Siddeley Engines Ltd. In 1902, Mr. J. D. Siddeley formed the Siddeley Autocar Co, and in 1904 his car, with a 6 h.p. single-cylinder engine, chain drive and three speeds, won the first award at the Small Car Trials. In 1905 the firm joined forces with the Wolseley Tool and Motor Car Co. Ltd., to form the Wolseley Tool and Autocar Co, and this association lasted until 1911. During this period a number of Wolseley Siddeley cars were produced, including the 30 h.p. landaulet supplied in 1907 to H.M. Queen Alexandra.

In the meantime, Capt. Deasy, an early motoring enthusiast,

began production of a Deasy car. As a result of collaboration between Capt. Deasy and J. D. Siddeley, the Deasy J.D.S. was produced in 1909. In 1911 J. D. Siddeley left the Wolseley Tool and Autocar Co. and the Siddeley Deasy Co. was formed. The Sphinx, now the bonnet motif of the Armstrong Siddeley cars, first appeared in the advertisements of the firm in 1913. After World War I, negotiations took place between the Siddeley Deasy Co. and Armstrong Whitworth, with the result that Armstrong Siddeley Motors Ltd. was formed in 1919.

To meet the demand in the early 1920s for a small inexpensive vehicle, the Stoneleigh light car was introduced. It had a twin-cylinder air-cooled engine and was marketed in 1923 by Stoneleigh Motors Ltd., a subsidiary of Armstrong Siddeley Motors Ltd. However, it is of course with medium and large size vehicles that Armstrong Siddeley have been so well known. In 1959, Armstrong Siddeley Motors Ltd. amalgamated with Bristol Aero Engines Ltd. and the company is now known as Bristol Siddeley Engines Ltd. For cars, however, the name Armstrong Siddeley is retained.

Daimler

It is not generally known that the Daimler Motor Syndicate Ltd. was founded 3½ years before self-propelled vehicles were allowed to be used unrestricted upon the public highways. The actual date of the founding of the company was May 1893. Later the British Motor Syndicate Ltd. absorbed the original company, and in January 1896 the Daimler Motor Co. Ltd. was registered. At the turn of the century, British-built Daimler engines were manufactured under certain patents of Daimler Motoren Gesellschaft, of Cannstatt. Originally, Gottlieb Daimler was on the board of directors of the Daimler Motor Co. Ltd. but, since he was unable to attend board meetings, he retired after a relatively short time. Thus all connection with the German organization ceased at a very early date. In the early years of this century the company did not do well financially, the original company wound up voluntarily and The Daimler Motor Co. (1904) was formed. There followed a period of extensive re-organization and, in 1905, the first dividend to shareholders was declared.

It was in 1910 that the B.S.A. and Daimler interests were amalgamated and the Daimler Co. Ltd. was formed, following the eventual liquidation of its predecessor. Among the noteworthy achievements of the company have been the combination of the fluid flywheel with the Wilson type gearbox, and the development of the famous sleeve valve engine. In 1923 steel sleeves, with white metal on their outer peripheries, were employed—in those days, this was no mean feat of engineering production.

The Lanchester Motor Co. was absorbed in 1931, and in 1933 the first Daimler car with a poppet valve engine, since 1908, was introduced. The sleeve valve system was finally abandoned in 1936. Immediately before World War II, the Birtley Co. Ltd., Hooper and Co. (Coachbuilders) Ltd., Barker and Co. (Coachbuilders) Ltd. and Associated Daimler Ltd. were absorbed into the organization.

During World War II, the Daimler organization was engaged in the manufacture of munitions, including the famous armoured Scout car which, in modified form, is still in production. Recent developments include the production of an entirely new V-eight engine which, in 2½-litre form powers the Daimler SP250, plastics bodied car, claimed to have a maximum speed of 120 m.p.h. In 4½-litre form, this engine powers the Majestic Major luxury saloon.

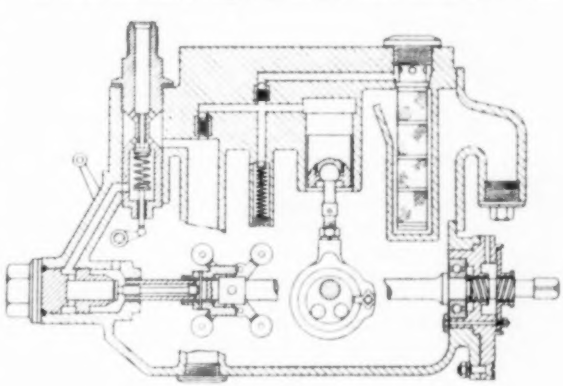
David Brown

Since we are concerned here solely with motor car manufacturers, it is only appropriate to outline in connection with the David Brown organization the history of Aston Martin and Lagonda. The original Aston Martin was introduced in 1913, and the company that produced it was at that time named Bamford and Martin Ltd., of 53 Abingdon Road, Kensington. This company was controlled by Mr. Robert Bamford and Mr. Lionel Martin. Originally the firm was established for doing motor repairs, and soon they secured the Singer agency for a large area of the South-East of England. They became a limited company in June 1913.

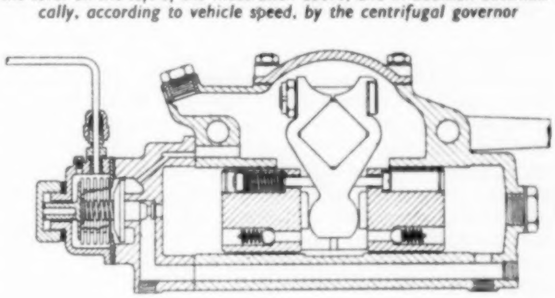
Their first car, in 1908, had an Isotta Fraschini chassis and a Coventry Simplex 1,400 cm^3 engine. After World War I the company was re-financed by Count Zborowski and taken over completely by Lionel Martin. In the period 1921-26 a few experimental four-cylinder, twin overhead camshaft engines were successfully raced all over Europe. Then, in 1927, the firm was taken over by A.C. Bertelli, and at the latter end of 1932 Aston Martin Ltd. was again re-financed by Mr. R. G. Sutherland. After World War II it was decided to concentrate on the production of an easily serviced 2-litre four-cylinder engine and, to facilitate servicing, the overhead camshaft was discarded in favour of pushrods. It was in 1947 that Mr. David Brown bought Aston Martin Ltd. and went ahead with the now famous DB models. One of the noteworthy technical features of David Brown vehicles is the employment of the space frame.

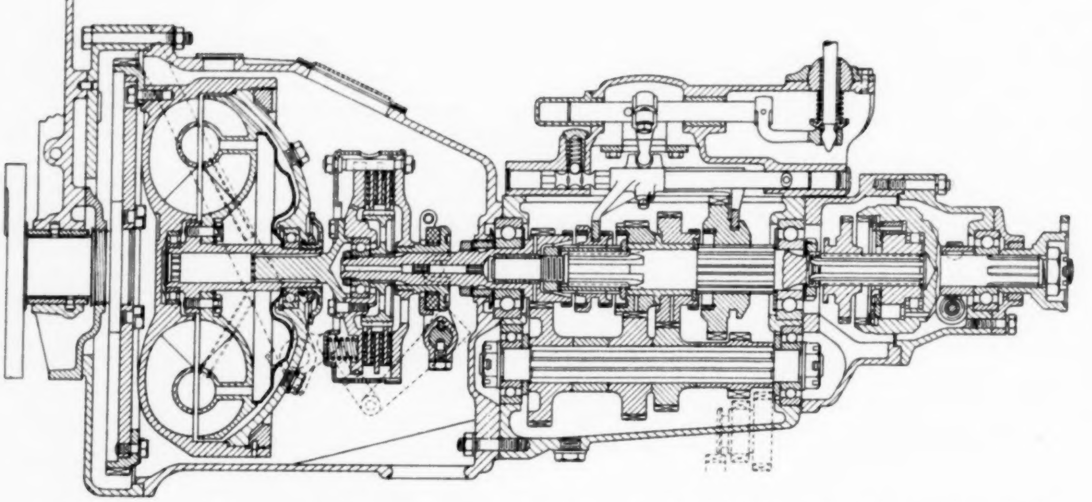
Despite its Continental-sounding name, the Lagonda car has always been a British production. In 1898 a young American engineer, Wilbur Gunn, came over from the States and teamed up with some British colleagues to produce a motor-cycle with a single-cylinder air-cooled engine. The first of these was actually built in the garden of Gunn's house at Staines, the site of the first Lagonda factory. The name of the firm was taken from Lagonda Creek, Springfield, Ohio, where Gunn spent his early years.

In 1904 the early Lagonda tricars were developed. The



Rolls-Royce ride control device, discontinued after World War II. Above: the gearbox unit, comprising a reciprocating pump, driven from the third-motion shaft, delivering oil through a check valve into a small surge chamber and thence out through the connection, top left, to the aneroid chamber controlling the blow-off valve in the damper, illustrated below. Pressure in the outlet to the damper is regulated manually, by the lever on the left of the illustration above, and in addition automatically, according to vehicle speed, by the centrifugal governor





Two pedal control is far from being a new development. It was obtained with the 1933 Singer Eleven, fluid-drive transmission

1909 four-wheel car produced by the firm was powered by an 18 h.p. four-cylinder engine and was the first British vehicle with an all-steel body and chassis. Lagonda was among the pioneers of supercharging, and in 1930 one of the cars achieved a speed of 90 m.p.h, while a fuel consumption of 20 m.p.g. was claimed; these results were obtained with an engine of only 14 h.p. by the RAC rating. Another out of the ordinary model produced by Lagonda was that with the V-12 engine, introduced in 1937. The cruciform chassis frame, with its independent suspension on all four wheels, was announced late in 1945. The company was acquired by David Brown in 1947 and, although there is not at present a Lagonda car in production, it is known that a new one is in the course of preparation.

Ford

The genesis of the Ford business in Britain was the American Motor Car Agency at Long Acre, London, which imported three model A passenger cars in 1904. However, the business was not properly established until 1905, when the Central Motor Car Co. was formed to distribute Ford products in the United Kingdom. In the following year, the late Lord Perry founded the firm of Perry, Thornton and Schreiber, who were to be exclusive concessionaires for Ford cars in Great Britain. It was not until March 1911 that the London branch of the Detroit company was registered, with P. D. L. Perry as managing director, in premises in Shaftesbury Avenue, London. In October 1911, owing to the increase in volume of business, the Trafford Park, Manchester, factory was opened. The English company now in existence was formed in 1928.

No history of the Ford organization would be complete without mention of the world famous model T, which was introduced in America in 1908 and continued in production until 1927. This car was also assembled at Manchester. It is generally known as the vehicle that changed the character of the motor car from a plaything for the wealthy to a near-necessity for millions of people throughout the world. Although at first the vehicle was imported in the c.k.d. condition from America, manufacture of components in this country was progressively increased until the product was virtually British made.

As the demand from European customers grew, it became apparent that the converted carriage works at Manchester would have to be replaced by a factory specially designed for large-scale automobile manufacture. The Dagenham site, mostly low-lying marshland, was acquired in 1925. Despite the nature of the land, its geographical advantages were indisputable. The fact that it was on the Thames gave it ready access to water transport to European ports. In addition, the general movement of industry towards the south was being encouraged, and the London County Council was carrying out a large-scale re-housing scheme centred on an estate bordering on what was then the village of Dagenham. A pool of labour was therefore readily available and the nature of the surrounding area allowed for future expansion.

Right from the early days in Manchester the company had been operating the Ford-pioneered system of flow production, and this also, of course, was continued and extended when operations began at Dagenham in 1931. Now it is the only motor manufacturer in Europe making its own pig iron—the blast furnace started operation in 1934. It also is the only motor factory in Europe making its own coke, coke oven gas and by-products: this plant has also been operating since 1934. Some measure of the progress made can be gained from the fact that in 1910 only 570 cars were sold whereas now vehicles of all types are being turned out at the almost fantastic rate of over 2,500 units per day at the Dagenham factory.

Jaguar

Jaguar Cars Ltd., of Coventry, have had what might fairly be described as a meteoric progress. Although they started by producing sidecars in 1922, it was not until 1931 that the first complete car having an identity of its own was produced by that company. Originally the firm was called the Swallow Sidecar Co., and was founded by W. Lyons and W. Walmesly. By 1928 the company had outgrown its two factories in Blackpool and moved to Coventry. At the same time the name of the company was changed to Swallow Coachbuilding Co. Ltd. Then, in 1933 a subsidiary company, under the title of S.S. Cars Ltd., was formed. The first S.S. Jaguar saloon was produced in 1935, but it was not until 1945 that the name of the company was changed to Jaguar Cars Ltd.

In the early days of the company, the manufacture of Swallow sidecars was the main occupation, but the production of motor car bodies increased as the firm grew. Up to

1931 special coachbuilt bodies were made on proprietary chassis, notably the Austin 7. These vehicles were sold through the normal dealers for the makes, but the word Swallow was added to the name of the car: for example, the Austin 7 version was called the Austin Swallow. For the S.S. series of cars, arrangements were concluded with the Standard Motor Co. to supply their engines and chassis modified to Swallow designs. The engines were equipped with special features such as aluminium cylinder heads, different carburettors and special manifolds to improve performance. By 1935, work was well advanced on a completely new range of cars under the title S.S. Jaguar. The first of these was a 2½-litre vehicle with an overhead valve engine, a cross-braced chassis with a wide spring base, all these components being designed by Jaguar. In 1937 the 1½-litre overhead valve engine was introduced, and the following year a 3½-litre engine was added to the range and installed in a vehicle with a new spot-welded box-section chassis frame. At the same time the body fabrication methods changed from the traditional coachbuilding to the employment of pressed steel components.

Among their most successful earlier models was the 3½-litre S.S.100 two-seater, which was one of only very few pre-war sports cars capable of a maximum speed of over 100 m.p.h. The story of the outstandingly good models more recently introduced is well known, and the increase of the power output of the XK engine from its original 160 b.h.p. to over 300 b.h.p, in competition form, exemplifies the advances that have have been made by this firm. Among the features that they have pioneered in this country are the disc brake and the Borg-Warner automatic transmission.

The announcement of the Rover gas turbine car was indeed a milestone in the history of the automobile industries of the whole world

Morgan

The Morgan Motor Co. Ltd. was started by H. F. S. Morgan, who had been pupil, later a draughtsman, at the G.W.R. works at Swindon. In 1906 the firm was started at Malvern Link; it pioneered two successful local bus services and became district agent for Wolseley and Darracq cars. The first Morgan car—a three-wheeler—was built in 1909. It comprised a light-weight tubular chassis, in which was installed a Peugeot air-cooled V-twin engine. It was tiller steered and had coil spring independent front suspension of practically the same layout as that currently employed in the Plus 4 model. Most of the mechanical components of the prototype were machined in the workshops of Malvern College. Manufacture in series began in 1910.

All the capital for the firm, which was registered as a private limited company in 1912, was supplied by H. F. S. Morgan's father, a clergyman, who remained chairman until his death in 1937. It is of interest to note that patent drawings were produced for the company by a young man who later became Sir John Black, chairman of the Standard Motor Co. This initiated the association which continues to this day with the employment of engines made by that company.

Rolls-Royce

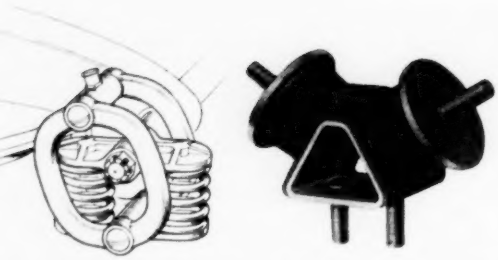
The firm of Rolls-Royce really began when F. H. Royce and A. E. Clermont started business in a tiny workshop in Cook Street, Manchester, in 1884, making lampholders and filaments for electric lamps, and later made a name in connection with dynamos and cranes. F. H. Royce had had a difficult start in life and had worked as a newspaper boy and as a telegraph boy in London. Not even in his wildest dreams could he have imagined that years later the most luxurious cars in the world, bearing his name, would glide silently along those streets that he was then tramping with telegrams. As a result of hard work and a flair for engineering on the part of Royce, the electrical business flourished until the Boer War started and a flood of cheap dynamos and cranes came into this country from America and Germany. Since, by then, it was equipment of this type that was the mainstay of Royce Ltd., which had been made a limited company in 1894, their business was in a very bad way.

However, rather than lower his standards to produce cheaper dynamos and cranes, Royce, in 1903, decided to venture into another field and build three experimental motor-cars of his own design. He came to the conclusion that, of the then existing cars, the most undesirable features invariably were noise and vibration, and in setting himself the task of improving on them, he laid the foundation of a policy of perfection from which he subsequently never deviated and on which the great reputation and success of his company has been built. His first model had a 10 h.p. two-cylinder engine and weighed 14¾ cwt. On 1st April 1904 the prototype was ready for the road. Close attention had been paid to silencing the valve gear and exhaust system, as well as to the meticulous workmanship and perfect assembly of every part, to eliminate all possible causes of noise and rattle.

Earlier in 1904, Royce was introduced to the Hon. Charles Rolls and Claude Johnson, who had recently become partners in the firm of C. S. Rolls and Co., automobile agents and dealers, London. As a result, the new car was exhibited, for the first time, on their stand at the Paris Motor Show in December 1904 and a vehicle was demonstrated outside the hall. It was most favourably received and of it the motoring correspondent of *The Times* wrote, "When the engine is running one can neither hear it nor feel it, and pedestrians never seem to hear the car's approach."

The outcome was that, under an agreement dated 23rd December 1904, it was understood that Royce Ltd. should supply C. S. Rolls and Co. with four different types of chassis. One was to have a 10 h.p. two-cylinder engine, one a 15 h.p. three-cylinder unit, the third a four-cylinder engine and the fourth a six-cylinder one. All of these vehicles were to bear the name Rolls-Royce.

On 16th March 1906, a new company known as Rolls-Royce Ltd. was registered. The motor-car section of the firm of C. S. Rolls and Co. ceased to exist as a separate entity, but Royce Ltd. continued in operation as manufacturers of electrical equipment until it was wound up soon after the death of Royce in 1933. From its inception the firm of Rolls-Royce Ltd., unlike so many of the other motor manufacturers, including most of those still in existence today, never found itself in really serious financial difficulties. When they planned to move to Derby in 1906, they had one of their nearest approaches to a financial setback. It looked as if the public issue of preferred and ordinary shares for the building of the new factory would be



Anti-vibration shackles such as that on the left were used on 1910 Standard cars and on various Daimler models; it is interesting to compare this device with the modern Metalastik Contrasonic shackle

under-subscribed, until a friend, Mr. A. H. Briggs, was approached: he subscribed £10,000 and literally saved the situation.

Later Rolls-Royce, as all know, achieved great fame and the highest possible reputation as manufacturers of aero-engines, in addition to motor-cars; however, that is another story. In 1931 they acquired the famous Bentley concern, makers of cars of primarily sporting appeal. In doing so they formed a new company, Bentley Motors (1931) Ltd. The firm of Bentley and Bentley was founded in March 1912, after the brothers H. M. and W. O. Bentley had bought a firm called Lecoq and Fernie, concessionaires for several French cars. G. P. de Freval who has previously been mentioned in connection with Alvis Ltd., was manager of their showrooms in Hanover Street.

In 1937 Rolls-Royce together with the Bristol Aeroplane Co. Ltd. formed a separate firm called Rotol Ltd., for the manufacture and development of variable-pitch airscrews. The following year the famous coachbuilding company Park Ward and Co. was acquired. Undoubtedly the steady progress of Rolls-Royce can be attributed to the fact that it has consolidated its position carefully as it has progressed, while never deviating from the original principle of accepting only matchless quality in its products.

The Rootes Group

Before the turn of the century, Mr. William Rootes, father of two boys named William and Reginald, was engaged in general engineering and cycle manufacture in Hawkhurst, Kent, and later, in 1898, opened a section to sell cars. But it was not until after World War I that the two Rootes brothers began their partnership, building up a flourishing car sales business in Kent and then opening premises at Long Acre, London. Thrupp and Maberly Ltd. joined forces with them in 1925. In 1926 the Rootes brothers took over Devonshire House, Piccadilly, and by 1928 were the largest distributors in England.

It was in this year that they decided to enter the manufacturing industry: the Rootes Group was formed in 1932, by the acquisition of the control of the Humber, Hillman and Commer companies. In 1934 Karrier Motors and in 1935 Clement-Talbot Ltd. were acquired. Then, in 1937, British Light Steel Pressings Ltd. joined the group and a year later the Sunbeam Motor Car Co. Ltd., which was immediately merged with Clement-Talbot Ltd. In 1950 Tilling Stevens, which just before World War II took over Vulcan Motors, became part of the Rootes Group. The latest two acquisitions were in 1955, when Singer Motors Ltd. joined the Group and in 1956 when a controlling interest in Tempair Ltd., of Dorking, was acquired. The latter are, of course, manufacturers of air conditioning equipment.

Of the member firms, Thrupp and Maberly is the oldest and has celebrated its 200th anniversary already this year. It started by manufacturing horse-drawn carriages, then the coachwork for steam vehicles and subsequently for cars. The next company on the Rootes Group list is that of Thomas Humber, who died in 1910. He established his company for the manufacture of bicycles in 1867, and the first Humber car was produced in 1899. By 1910 Humber had established itself as a manufacturer of quality cars in a well equipped factory in Coventry, which now, much extended and modernized, is the centre of the Rootes Group car manufacturing organization.

The Hillman Motor Car Co. Ltd. was founded in 1907 by the pioneer motorist Mr. William Hillman, and his first car was built in 1908 to compete in the Tourist Trophy race of that year, in which he put up the fastest lap time. The famous Minx range, which first appeared in 1932, has been in production continuously since then.

The Commer Car Co. was originally formed in 1905, for the manufacture of commercial vehicles, under the name of Commercial Cars Ltd. It did not take its present title of Commer Cars Ltd. until it joined the Rootes Group. Karrier Motors was established in 1907, but it was not until 1918 that it began to specialize in vehicles for municipal purposes. The other company in the commercial vehicle section of the Rootes Group, namely Tilling Stevens Ltd., was founded in 1897 at Maidstone.

British Light Steel Pressings Ltd. is relatively a newcomer, for it was founded in 1930 and for many years made a wide variety of pressings for almost every trade but the motor industry. It was only when the organization was taken into the Rootes Group that it began making body shells. John Marston, who first entered business on his own account in 1859, founded the Sunbeam Cycle Co. in 1887. The first Sunbeam car was built in 1899 and was simply an experimental model. By 1901 production of the Sunbeam-Mabley commenced. This was a four-wheel car with three tracks, that is, the wheels were arranged one at the front, one on each side at the centre, and one at the rear. It had tiller steering at the rear operating on both the front and rear wheels, and it was powered by a 2¾ h.p. engine. By 1904, cars of up to 16 h.p. were being produced by this firm. Sunbeam was among the first to produce six-cylinder cars and subsequently became famous in racing circles. It was the first to achieve the record speed of 150 m.p.h, in 1926, and then over 200 m.p.h, in 1927.

The first Talbot cars were manufactured in 1904 by Clement-Talbot Ltd., whose chairman was the Earl of Shrewsbury and Talbot. They included vehicles powered by two- and four-cylinder engines, from 8 to 27 h.p. This firm, too, became famous for its racing cars. At first, when the Sunbeam and Clement-Talbot companies were merged on joining the Rootes Group, their cars were given the name Sunbeam-Talbot. However, because of the confusion that arose among the general public on account of the fact that cars were also being manufactured by the French Talbot company, the second part of the name was soon dropped.

George Singer began manufacturing the world's first safety bicycle in Coventry in 1875 or 1876. There must be many people who are under the impression that motorized wheels are a modern invention, but Singer and Co. Ltd. were producing bicycles and tricycles with motorized wheels in 1902. In 1904 the first Singer two-cylinder two-seater car was built.

Rover

The foundations of the Rover Co. Ltd. were laid in the year 1877. Two engineers, John Kemp Starley and William Sutton, joined forces to manufacture bicycles of the penny-farthing type. Sutton soon withdrew from the partnership, and Starley turned to making bicycles of what are now regarded as the conventional design, that is, driven from the rear wheel. About the year 1896, J. K. Starley and Co.

became the Rover Cycle Co. and, in 1903, began to make motor-cycles. Almost immediately the decision was taken to build motor-cars, and the first of their four-wheel vehicles appeared in 1904. In recent years, of course, the Land-Rover introduced in 1948, has had noteworthy success as a cross-country vehicle. Perhaps one of the most outstanding achievements of the Rover Co. has been the production of the gas turbine car, for which they received the Dewar Trophy in 1951. This car was officially tested by the Royal Automobile Club on the 8th March 1950.

Standard

Among the very few firms that were originally founded for the sole purpose of manufacturing motor cars is the Standard Motor Co. Ltd., which was started by Mr. R. W. Maudslay in 1903. The name Standard was adopted because it was the company's intention to manufacture a number of cars of identical design, as opposed to the then more usual procedure of building individual vehicles to special orders. The first tiny factory operated by the company was at Much Park Street, Coventry, and the car originally produced was a single-cylinder, 6 h.p. model with shaft drive and a three-speed gearbox. By 1912 the company owned a factory at Cash's Lane, Coventry, and one of the first light cars, a 9·5 h.p. four-cylinder vehicle was produced there by them.

The company had centralized its car manufacture at Canley by 1936. At this time, too, an aero-engine shadow factory was put into operation near the Canley establishment, and in 1939 another one was completed at Banner Lane. The assets of the Triumph Motor Co. Ltd. were acquired in 1945, and an agreement was concluded to manufacture the Ferguson tractor at Banner Lane.

By 1950 the company had successfully designed and developed a light four-cylinder diesel engine, for use primarily in the Ferguson tractor, and this unit has since been adapted for many other commercial applications. Recently, of course, the tractor plant at Banner Lane has been sold to Massey-Ferguson Ltd. and as a result of this change and also the acquisition of firms such as Beans Industries and Mulliners Ltd., the holding company has adopted the name of Standard-Triumph International Ltd. Nevertheless, the car-producing company is still the Standard Motor Co. Ltd.

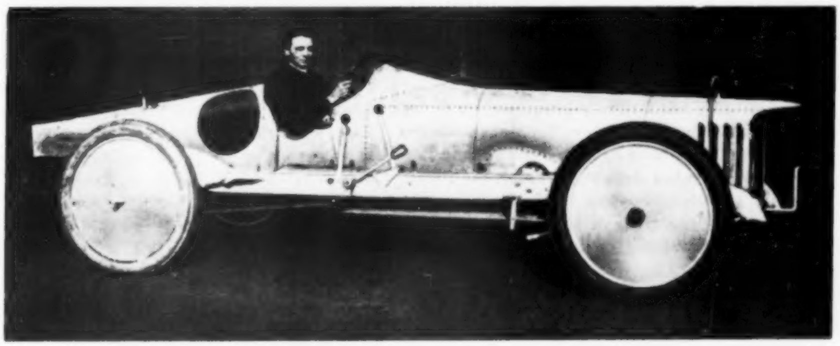
Vauxhall

Before starting the history of Vauxhall it will not come amiss to trace the far more ancient story of its crest—the Griffin. It has romantic associations reaching back to the time of King John. Fulk le Breant, who lived in those days, was an adventurer and soldier, who adopted the Griffin as his crest. By order of King John, he married Margaret de Redvers, widow of Baldwin de Redvers, son of the Earl of Devon. By that marriage Fulk acquired his wife's property in Lambeth. The house became known as Fulk's Hall and over the years this was gradually corrupted to Fawkes Hall and thus to Vauxhall. The Griffin was used as a sign for the famous Vauxhall Gardens; and when Mr. Alexander Wilson founded the Vauxhall Iron Works, he adopted Fulk's historical crest as a trade mark for his factory.

Now comes the most interesting part of the story. When the Vauxhall Company had to find room for expansion, the site chosen was Luton. And it was not until some years after that the discovery was made that Luton was the original home of Fulk le Breant, whose castle had stood close by the site chosen for the factory. Coincidence had brought the Griffin home.

The first Vauxhall car was placed on the market in 1903 by the Vauxhall Iron Works Co. Ltd., in the Wandsworth Road, London—this firm had been founded in 1857, by a Scottish engineer Alexander Wilson, for the manufacture of marine engines, and it became a limited liability company in 1892. In 1905 the motor manufacturing section of the company moved to Luton, and then Vauxhall Motors Ltd. was formed in 1907. A milestone in the progress of the firm came in 1927 when the agreement with the General Motors Corporation, by whom the company was taken over, was ratified. From then on Vauxhall Motors Ltd. were in an entirely new field, that of mass production.

So much for the car manufacturers, but we cannot end this story without paying a tribute to the great contribution that has been made to the industry by the component and accessory manufacturers. Throughout the history of the industry, they have supplied at an almost unbelievably low cost many of the major, as well as minor, components that are assembled into the car; and they have pioneered much of the equipment when the demand was small, but which is now accepted as standard. The industry owes them a great deal for their foresight and their tireless research and development.



Vauxhall 20 h.p. car driven by A. J. Hancock at 100·08 m.p.h. over the flying half-mile in the year 1910

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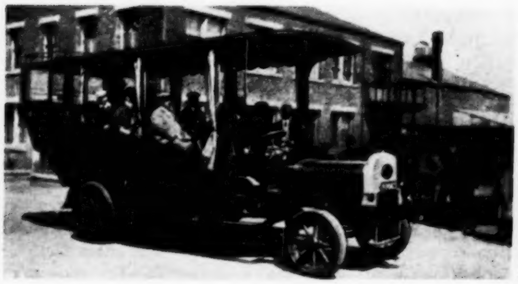


The two illustrations above are, from left to right: Fig. 5. A Leyland char-a-banc of the 1910 period, with a 30 h.p. petrol engine, four-speed gearbox and a worm axle; Fig. 4. Foden steam wagon of about 1910, with a horizontal multi-tube boiler and an engine of about 50 b.h.p.

HALF A CENTURY OF PROGRESS

The Romance of Fifty Years of Commercial Vehicle Design and Development

SIR HENRY SPURRIER, M.I.Mech.E., M.I.T.E.*

To cover the field of commercial vehicle development adequately over a period of fifty years would be a difficult and lengthy assignment. So in this short review the author must deal only with the revolutionary, and accordingly the most interesting, features of that development.

The year 1910 marked the end of the Edwardian period, during the crowded decade of which the greatest advance—probably of all time—was made in new methods of road transport. At the turn of the century, the roads of Great Britain were traversed entirely on foot or by horse-drawn transport, with the pedal cycle representing the only new individual form of rapid transport in general use.

For twenty years prior to 1910, the evolution and development of mechanically propelled road vehicles was almost entirely in the hands of a few enthusiastic pioneers who, by virtue of their faith in this objective, were able to surmount the scorn and ridicule poured on them from every quarter. Their perseverance in the face of adverse criticism is a story of courage and tenacity, and it is at this stage that I take up the story.

By 1910 the petrol engined motor-car, and lorries driven by steam or internal combustion engines, had passed through their early invention and development stages, and had become accepted—if not always welcomed—by the public, as the new form of road travel for the individual and for the transport of goods from door to door. At that time, three distinct types of vehicles were established and rapidly coming into use: they were the motor-cycle, the motor-car and, developed from the motor-car, the commercial vehicle.

*Chairman and Managing Director, Leyland Motors Ltd.

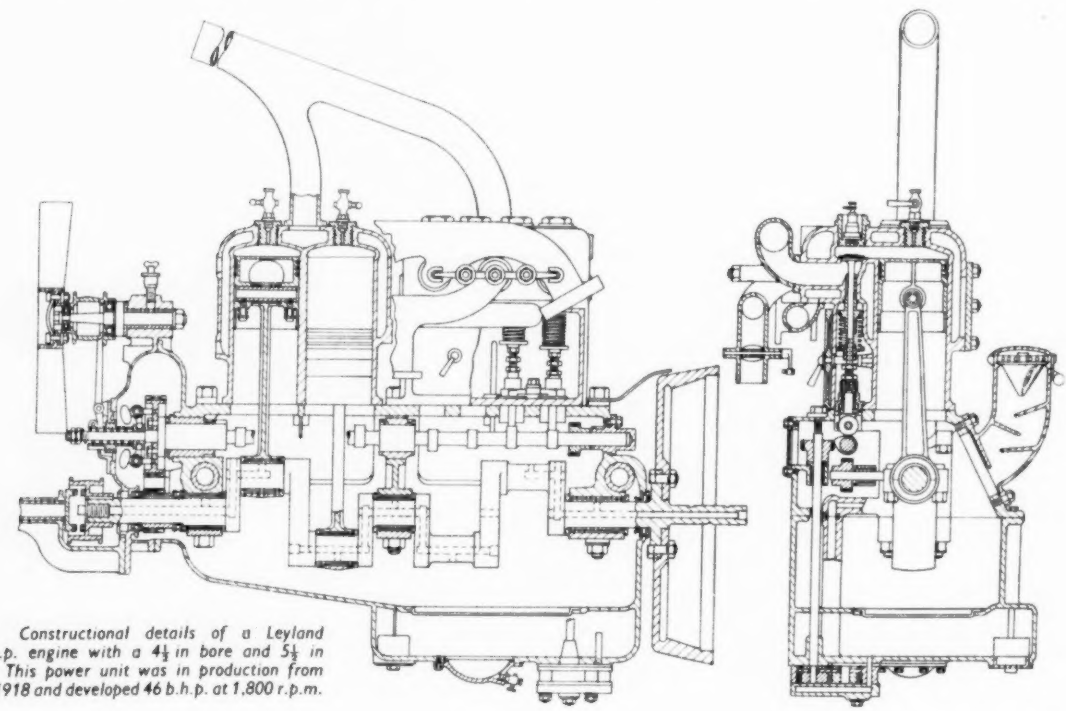


Fig. 1. Constructional details of a Leyland 36/50 h.p. engine with a 4½ in bore and 5½ in stroke. This power unit was in production from 1910 to 1918 and developed 46 b.h.p. at 1,800 r.p.m.

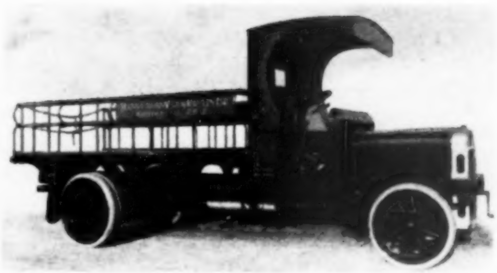


Fig. 3. A 5/6 ton lorry typical of those produced by Leyland in the period 1910 to 1912; it had a four-cylinder petrol engine

It is on this last type that I wish to write in this article.

Petrol engines for vehicles had by then arrived at a state of reliability and marked similarity of design. Early features such as tube and low-tension ignition, surface type carburettors, automatic inlet valves, and other devices, now almost forgotten, had been tried out and discarded, leaving a power unit that has remained basically the same up to the present day. Most four-cycle engines then had:

Four cylinders
Poppet type valves
A jet and venturi type carburettor
High-tension type magneto or battery and trembler coil ignition
Positive pump-feed lubrication.

The engine's safe maximum speed was approximately 1,500 r.p.m, and its rated h.p. was based on an R.A.C. formula, which took only the bore into account. In general, the maximum power developed was approximately 10 b.h.p/litre capacity. A typical engine of 1910 is the Leyland S 5 36 h.p. model, Fig. 1.

Clutches were almost entirely of cone design, though in certain makes the patented Hele-Shaw multiple plate clutch was used. Gearboxes gave three or four speeds, and were of the sliding engagement, spur gear design. The quadrant change, employed almost universally on earlier designs, had become superseded by the modern and more handy gate.

The propeller shaft drive passed through a totally enclosed spherical universal joint and a torque tube to a rear axle, of the double-reduction bevel and spur type; or, as an alternative, an overhead type worm and wheel. Certain manufacturers employed a bevel countershaft directly behind the gearbox, with chain-and-sprocket drive to the dead rear axle.

Brakes were on rear wheels only and were of the internal expanding type operated by a hand lever, rods and a compensating gear. It was common practice to have a footbrake operating on the transmission. This brake generally comprised a pair of external contracting shoes acting on a drum mounted directly behind the gearbox. Cast steel spoke type or steel plate wheels were employed, but American vehicles invariably had the wooden, artillery type. Solid rubber tyres moulded on to a steel ring were hydraulically pressed on to the wheel. Shown in Fig. 3 is a typical example of the Leyland 5- and 6-ton petrol chassis of 1910: it has a cab—without a windscreen—a coachbuilt body and oil side and tail lamps. The price was £735 complete.

I switch now to the steam wagons of the same period, because it was during these few years, before World War I, that steam engined road vehicles had reached their peak of development and, although continued in production and still popular with the operator, particularly for such purposes as dock work and municipal engineering services, this type was gradually becoming uneconomic and being replaced by the internal combustion engine.

Two schools of thought had been applied during the early stages of development: one believed in solid fuel for firing, and the other was equally adamant that oil was better. Some experimented and made both types and, in most cases, finally adopted solid fuel—coke—as their standard.

Just as there were two schools in the matter of fuel used, so also were there two in boiler and chassis design. Broadly these were in favour of, on the one hand, the horizontal tube locomotive type, and on the other, the vertical tube boiler as used in many stationary engine designs. The former arrangement was employed mainly in road traction engines and agricultural tractors, ploughing engines and steam rollers. Foden lorries were the exception and, to the end, remained faithful to the locomotive type for all purposes.

There is not adequate space here to describe in detail the features of the many makes. I give, therefore, only a general outline of practices employed, with some representative specification drawings and pictures of these wonderful and romantic old vehicles.

Leyland steam wagons

These old steam wagons ranged from 3 to 6 tons payload. Boilers were of the central feed, vertical fire-tube type; the

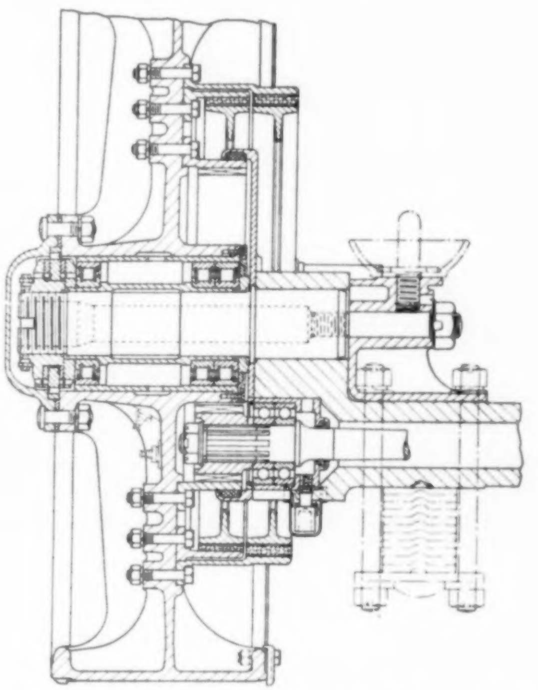


Fig. 2. A feature of the L.G.O.C. NS Bus was the hub reduction axle

steam was superheated and at 250 lb/in² pressure; and a horizontal two-cylinder double-acting compound engine was employed. This power unit normally developed 40 b.h.p. but was capable of delivering 60 b.h.p. when required. Its maximum operating speed was 450 r.p.m. The engine and the two-speed gear and differential were contained in one casing, and the final drive was by chain and sprocket. There was no condenser, and a 75 gal water tank was carried at the back of the chassis: this provided for a range of approximately 30 miles between replenishments, sufficient for the type of duty on which these vehicles were employed.

It is interesting to note that insofar as tyre equipment was concerned, steel bands pressed on to composite wheels was the general standard, but solid rubber tyres were offered, at an extra charge, with the claim that, so shod, the

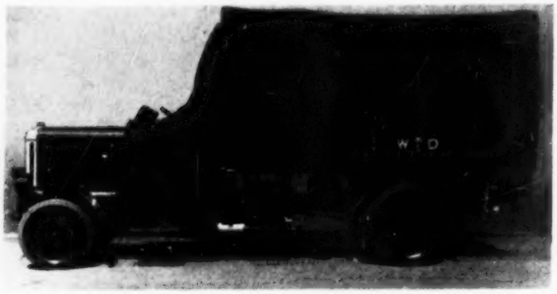


Fig. 6. A typical W.D. subsidy vehicle for World War I; it had a 36 h.p. petrol engine, four-speed gearbox and double-reduction axle

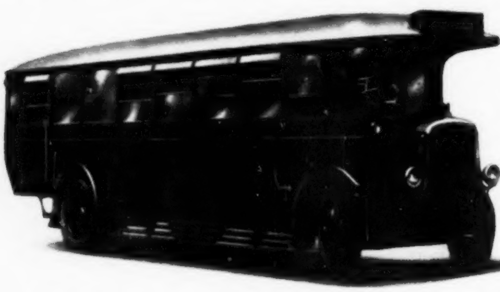


Fig. 7. In 1925 the Leyland Lion single-deck vehicle represented the first attempt to produce a specialist chassis for a passenger vehicle. Its frame was designed so that all the components could be kept low down, and the vehicle had servo operated brakes on all of the four wheels

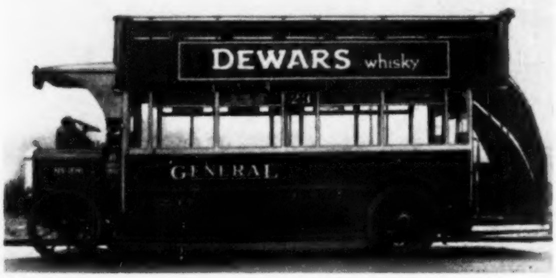


Fig. 8. A.E.C. double-deck bus of the NS type, of about 1927; its special feature was a hub reduction rear axle to enable the lowest possible platform height to be obtained, for passenger convenience

wagon was capable of 75 to 100 per cent more work. The price for the 6-tonner—complete with flat body—was £877.

The Foden steam wagon

The boiler, of the horizontal multi-tube type, formed the front part of the frame. It could be fired with coke, coal or wood and supplied steam to a compound engine fixed on the top of it. The advantages claimed for this layout were that the engine was readily accessible and operated with dry steam. Both cylinders—4 in and 6¾ in diameter—were fitted with a high-pressure gear by means of which, in case of emergency, they could each receive live steam from the boiler, and exhaust independently. Reversing was effected by the conventional link motion. The power was transmitted by a pair of spur wheels driving through an extra strong roller chain to a compensating gear. There were two speeds, the overall ratios being 9 : 1 and 24 : 1. The vehicle could haul a payload of 5 tons, plus 2 tons on a trailer, at an average speed of 6 m.p.h. and could traverse 20 miles without taking on water. Fully laden, it could climb a gradient of 1 in 6. The vehicle was mounted on laminated springs, and the construction of the artillery wheels, Fig. 4, is interesting in that they were extra wide for traversing soft roads.

So far, only the field of goods vehicles has been considered, but by 1910, petrol and steam engined motor-buses were running in many cities, particularly London, though inter-urban services were still to be developed on a large scale. Private hire coaches, then known as char-a-bancs, were becoming very popular, and I well remember many such tier-seated vehicles, Fig. 5, with their cape-cart hoods and weather curtains, carrying their loads of holidaymakers from all over industrial Lancashire to Blackpool. Basically, these passenger models were of the same design as the equivalent lorries. They had, nevertheless, certain refinements, such as a longer wheelbase, more flexible springing, higher back axle gearing, and always rubber tyres. They remained in this form up to the beginning of World War I, and were re-introduced, with very few changes, for the first four or five years after the war.

At the end of the period 1910 to 1913, ominous clouds of war were beginning to appear on the eastern horizon. The government of the day had even then begun to realize the important part mechanical transport could play in any future war, and whilst the horse was still the prime mover for all artillery and supplies, a mechanical section of the then Army Service Corps had been established. This section had motor-lorries, tractors and mechanical handling aids, all of which were at the development stage, and in certain cases this development was encouraged by a subsidized plan in which certain commercial manufacturers took part. Well known names at that time were Albion, Dennis, Halford, Leyland and Thornycroft.

Much credit must be given to those early mechanically minded pioneers of the British army who, in spite of considerable prejudice and opposition from the dyed-in-the-wool old-time regulars, were not to be deterred. When war broke out, in August 1914, they were able to show a range of WD-approved vehicles and tractors—an example from which is shown in Fig. 6—which was not only in being as new equipment in the Army Units, but for which production arrangements had already been made with the manufacturers, to meet any emergency arising from sudden aggression by a foreign power.

Needless to say the petrol engined vehicles formed the basis of all this equipment. Steam had to be ruled out on account of the difficulties of supplying fuel and water under all circumstances. These vehicles became known as subsidy types. They served the forces magnificently throughout the whole war and, curiously enough, remained almost unaltered in design during that period, and in fact continued to be sold in their original form to private operators and so were of use to the civilian community for several years after hostilities had ceased.

The period between the wars

This period in the history of British commercial vehicles must be within the memory of most adult readers. It can justifiably be described as the motor age, marking an era when motor vehicles of all descriptions became firmly established as the new and universal form for travel and transport on the roads.

Commercial vehicles began to make rapid strides in development. Buses no longer were made from goods type chassis. Pneumatic tyres were introduced and, after a somewhat uncertain start, made rapid strides in replacing for ever the solid rubber tyre. High-speed lighter-weight petrol engines were developed to take the place of the old slow and rough units of pre-war design. Transmissions were improved

and power-assisted four-wheel brakes were introduced. Probably at this stage more attention was given to improving passenger than goods vehicles, for the obvious reason that the public had suddenly become bus travel conscious and was demanding improved speed and comfort.

Early examples of these new creations were the Tilling Stevens Express, the Leyland Lion, Fig. 7, and the Midland Red S.O.S.—all single deckers. With regard to double deckers, The London General Omnibus Company showed the way by putting into service the revolutionary NS type, Fig. 8. This vehicle incorporated a hub reduction, dropped type rear axle, Fig. 2, thereby allowing a low floor level for ease of entry; it was the first of its type in the world.

Leyland Motors can take credit for the next stage in revolutionary passenger and goods vehicle design. A complete range of new vehicles was evolved and produced under the direction of Mr. John Rackham, then Chief Engineer to the company, who had joined Leyland from a similar post in America and had brought revolutionary ideas with him. He based his theories on the belief that a commercial vehicle should perform and behave as a car and not as the rather rough, heavy and cumbersome machine that it had been up to then.

When Mr. Rackham's task was completed, his vehicles embodied the following new features and improvements:

A six-cylinder, high-speed, 120 h.p, overhead valve, petrol unit.

A light, constant-mesh, dog-engagement type gearbox assembled with its engine to form a single unit

Powerful, vacuum operated, four-wheel brakes

In the case of the passenger models, a low floor height, achieved by off-setting the housing of an underslung worm-drive rear axle, Fig. 9.

Light steering

Long and flexible springs, with high deflection, to give a low periodicity for a laden bus

In addition, as a complement to this new chassis, he designed a double-deck, all-enclosed body that was to become world famous, in that it was the original of what is now generally known as the low-bridge type vehicle.

Engine development

Since a review of engine development appears elsewhere in this issue, reference here will be made only to the effect of engine types on chassis development. The spark ignition engine, using petrol as its basic fuel, had reached a high standard of performance and reliability by 1930, but at this stage was being quickly superseded in the heavier commercial vehicle field by the compression ignition engine, which began to be adopted for road transport about that time.

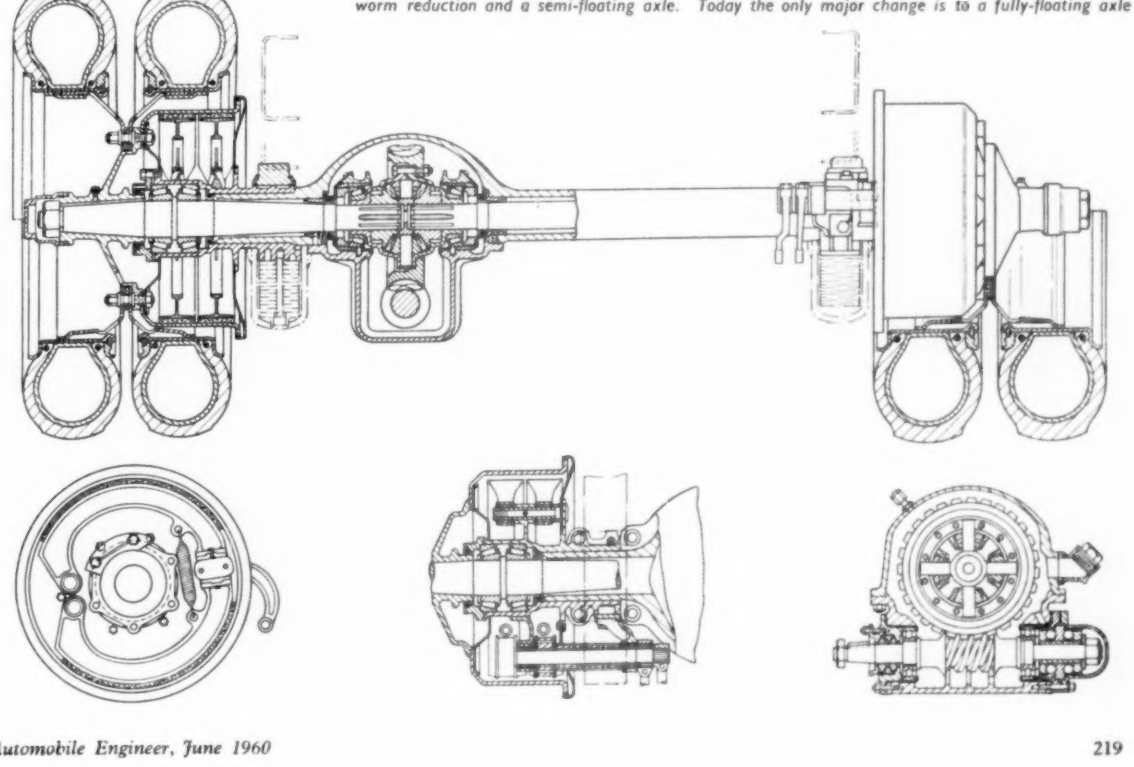
Although the Finance Act of that period permitted gas oils, without tax, to be utilized in place of petrol, it was quickly shown that the specific performance of the compression ignition engine was so markedly superior that it was bound to become the ultimate objective. Fuel consumption on city service work was halved and, finally, the obviation of both electrical failures and high operating temperatures gave a degree of reliability under arduous service conditions which was previously unknown—but not, of course, without much development.

In the intervening period the compression ignition engine has been scaled down in size, the specific output has been materially increased, and developments have taken place, not only in the use of the four-cycle engine but in the two-cycle and the opposed piston types such as the Foden and Rootes engines respectively. Today it is not uncommon to be able to achieve 250,000 miles of city service bus operation without any major maintenance operations.

Transmissions

It is interesting that, in the conception of a transmission, little change has been made from that of the earlier vehicles, of 1900: even today, the basic principle of the four-speed transmission remains the same; it is still the simplest and

Fig. 9. The Leyland offset drive for the Titan double-deck bus of 1927, which had an underslung worm reduction and a semi-floating axle. Today the only major change is to a fully-floating axle



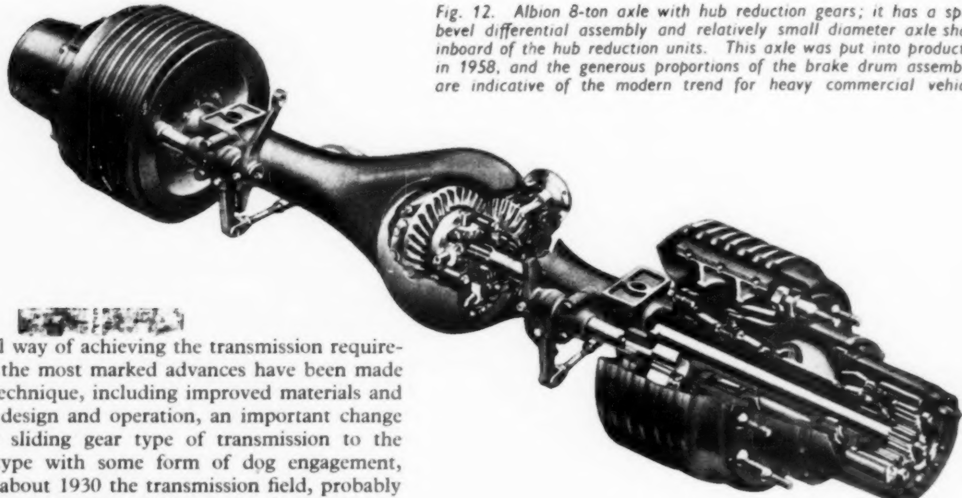


Fig. 12. Albion 8-ton axle with hub reduction gears; it has a spiral bevel differential assembly and relatively small diameter axle shafts inboard of the hub reduction units. This axle was put into production in 1958, and the generous proportions of the brake drum assemblies are indicative of the modern trend for heavy commercial vehicles

most economical way of achieving the transmission requirement. Possibly the most marked advances have been made in gear design technique, including improved materials and compactness of design and operation, an important change being from the sliding gear type of transmission to the constant-mesh type with some form of dog engagement, Fig. 10. Since about 1930 the transmission field, probably more than any other, has exercised the minds of design teams. The phases of development are: ease of gear selection by the use of synchromesh dogs; the development of the planetary type of transmission with forced engagement, first manually and then by air operation, leading up to semi-automatic control by means of air or hydraulic assistance, Fig. 11. Having arrived at an air assisted transmission, the adoption of an electrically controlled system to make this fully automatic was a natural development.

By virtue of the inherent characteristics of the internal combustion engine, it is of course essential that there be a torque absorbing medium between the power unit and the transmission. Within the period under review, considerable detail development has taken place on the single-plate clutch; this work has been aimed principally at giving smoothness of operation coupled with a high degree of reliability under conditions of abuse in service. In relation to the planetary transmission, a coupling of the hydrokinetic fluid type was introduced in order that the vehicle could be accelerated from rest without utilizing the operating band in the transmission. This combination, developed under Daimler-Martin patents, is still popular for passenger vehicles of the city service type, the gearbox being of the Wilson (Self-Changing Gear) design.

In the early 1930s, attempts were made to produce an automatic transmission based on the hydrokinetic torque converter. The Swedish firm of Lungström had produced a polystage unit capable of a stall torque ratio of 5 : 1 and with peak hydraulic efficiency of the order of 84 per cent. This unit was further developed by Leyland Motors and a direct-drive clutch was incorporated to isolate the torque converter; in this form it found considerable application for city service operation up to the outbreak of World War II. Experience with the unit proved that a transmission of this type had to be carefully matched both to the characteristics of the power unit and to the vehicle into which it was installed. It therefore did not have the same latitude of application as had a

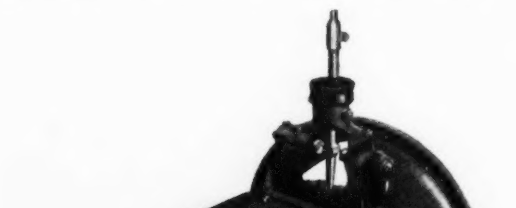


Fig. 10. Above: Typical modern truck gearbox with constant mesh gears and available with five or six speeds; a power take-off is also incorporated. Simplicity is the keynote of transmission design

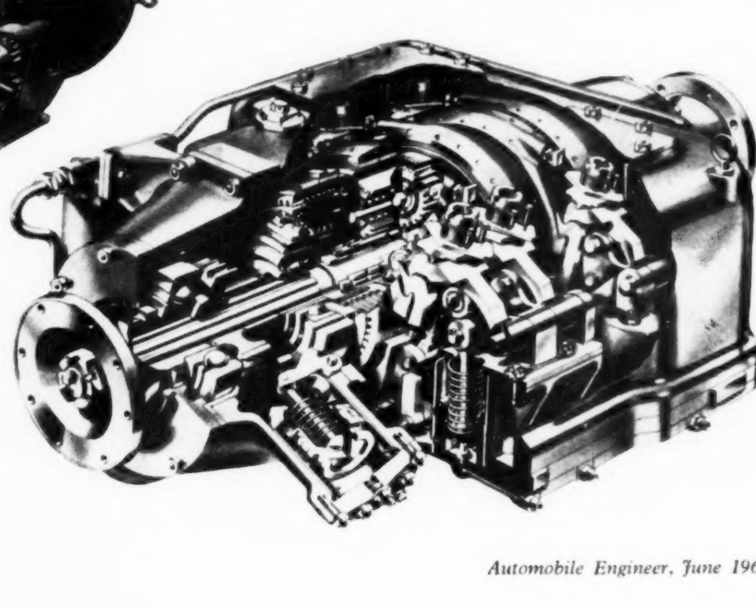


Fig. 11. Right: A Wilson type gearbox incorporating a self-adjusting mechanism to take up wear of the annulus brake bands; it has been in production since 1950, and is also available with either semi- or fully-automatic control, and with four, five or eight speeds. The unit is suitable for use with engines developing 150 to 200 b.h.p.

conventional transmission; also, its operating cost so far as fuel consumption was concerned was higher; consequently the unit lost popularity. It is significant, however, that in the United States, where fuel costs are lower, this form of transmission is still highly popular, particularly for congested city service with one-man operation of the vehicle.

Sporadic attempts have been made to introduce variants of the conventional gearbox—that is, other than the planetary type developed by Wilson. In the early 1920s, the inertia type of torque converter, such as the Constantinesco and de Lavaud, had considerable technical interest but was doomed to failure by the inability to provide a reliable one-way valve mechanism.

In considering public service transport, full recognition must always be given to the great service rendered by the tramcar in its heyday. However, its lack of manoeuvrability was a serious drawback, and it was succeeded by the well known trolley-bus. Its quietness and overall performance made it a popular form of transport but nevertheless it suffered, though to a lesser degree, from being insufficiently flexible and it is now considerably less widely used. Other transmission arrangements that have been employed include that of the Tilling Stevens petrol-electrical vehicle, with a generator coupled directly to the engine and supplying power to the driving motor. This bus, whilst offering tramcar characteristics, eventually lost favour owing to its weight, cost, and low overall efficiency. The Thomas transmission, developed by Hedley Thompson, Parry Thomas and Leyland, was an improvement on the simple generator-and-motor type, insofar that the overall efficiency was considerably higher, but it was complicated and heavy and fell from favour.

Propeller shafts coupling the transmission to the final drive have gone through several phases of development. First the simple Cardan joint was used, then flexible discs and finally Hardy Spicer or Mechanics type joints, with needle roller bearings, which are now universally adopted on all types of vehicle.

Suspensions

It is remarkable that the earliest conception of the laminated semi-elliptic spring has remained with us so long, and it points to the fact that the original conception was in effect a stroke of genius almost comparable with the invention of the wheel. The first major break-away from this conventional system was on the motor-car, where independent front suspension produced improved riding characteristics plus the ability to mount the power unit much lower in the front structure; it is significant that only sporadic attempts have been made to introduce this form of suspension on commercial vehicles in the heavier classes. Leyland, A.E.C, Midland Red and others have approached the problem from different angles and will be referred to later in connection with vehicle development.

At this stage, it may be appropriate to make reference to the drastic improvement in the pneumatic tyre, which obviously can be treated as part of the suspension system. Durability and carrying capacity have been greatly improved by the use of different forms of construction in the carcass of the tyre and, latterly, by the use of steel woven material and of man-made fibres instead of cotton. The balloon tyre was in vogue about 1925 but has now been superseded by moderately low-pressure tyres used in conjunction with improved suspension systems.

After World War II, considerable attention was given to this problem of suspension. Rubber in shear, giving the desirable feature of a non-linear load-deflection law, has had some success—Midland Red—but is not as yet a universal feature. Again, in the early 1950s, an attempt to utilize air as the suspension medium was made in America, principally for public service vehicle use. These systems have the merit of giving controlled platform height under widely varying load conditions but can exhibit objectionable characteristics in respect of roll; therefore, it is possible that some combination of either rubber or air with the conventional leaf spring may be the ultimate answer. An interesting recent development is the L.T.E. Routemaster bus, having an independent front suspension unit with coil springs, and what is termed a *wheelbarrow* type rear suspension frame, with either air or coil springs between it and the vehicle structure. From the foregoing paragraph, it can be concluded that there is still much ground for development in suspension systems for the different classes of commercial vehicles.

Fig. 13. The L.T.E. Routemaster double-deck bus of integral construction was introduced in 1958; it has independent front suspension and a wheelbarrow type frame for the suspension units at the rear, also an accumulator in the hydraulic system for the brakes and power steering

Steering gear and axles

Except where independent front suspension is employed, the conventional conception of front and rear axles comprising beams to which are attached the wheel and suspension units still persists. The earliest form of steering gear was the rack and pinion, and this was followed in turn by the worm and quadrant, the worm and nut, and later the high efficiency type of cam mechanism, which is now predominant. Variants of the cam mechanism are well known, and the recirculating-ball type, complicated though it may be, is attractive in that it reproduces the good features of the worm and nut but at very high efficiency.

As axle weights and tyre sizes increased to meet requirements both at home and abroad, some form of power assistance for the steering mechanism was desirable. Such forms exist either as fully integrated units or with a control valve in the steering gear and a separate jack; air or hydraulic power is of course utilized. Power assisted steering is as yet by no means a standard feature, but no doubt it will become so as operating speeds increase, and the need to give complete ease of control by the driver is acknowledged.

Since World War I, more attention has been given to vehicles for both military requirements and overseas development. In these vehicles, driving axles are employed at the front, together with compact universal joints such as the Tracta and Rzeppa units or the more simple type employing bevel gears round the kingpin.

With regard to rear axle development, little has altered during the last fifty years. Even at the beginning of this period, the overhead worm, as the means of drive, was well established as also was the double-reduction, spiral bevel

Fig. 14. A Leyland eight-wheel vehicle designed for a gross weight of 24 tons; it is powered by a 125 b.h.p. diesel engine and has a five-speed gearbox, tandem worm-drive axles and air-operated brakes. The general layout is typical of today's heavy commercial vehicles

and spur gear type. The weight of the component for a given job is of primary importance, and for this reason, production techniques were developed to allow the single spiral bevel and pinion to be introduced, Fig. 12, and later, as an alternative, the hypoid type.

The conception of the differential, the spider and bevel gear assembly, has changed remarkably little. For cheapness, semi-floating drive shafts were used in many early automobiles. They had the disadvantage, however, that in the event of failure the wheel assembly became completely detached. The fully floating axle is now firmly established as today's standard.

Rear axle designs must incorporate the greatest practicable safety factor. The practice of using a one-piece forging was introduced about 1927 and lends itself admirably to the off-set type of axle, for example, with the differential assembly close to one side. For the lighter type of vehicle, the pressed steel welded construction axle is universally popular. Cast steel centre sections with pressed-in steel tubes are widely used, and axles of the two-speed type, to give an extended range of performance, have come into vogue on the lighter type of vehicle.

Braking

A primary requirement for road vehicles is the ability to retard them adequately under any conditions of load and speed. By the introduction of the Road Traffic Act in 1930, a more rigid control of construction and use was imposed, with particular emphasis on roadworthiness and safety. Accordingly, braking layouts and their effectiveness featured high in the list of the Act's new requirements—prior to this vehicles were often very badly overloaded and in many instances had braking systems that were inadequate even for the normal laden condition. Considerable limitations were imposed on the brake designer, in that the Regulations demanded that the drum itself must be attached to the road wheel.

The gradual development of the braking system has been predominantly in connection with the use of some form of servo assistance. In the early 1920s, the late Parry Thomas, for his Leyland Straight '8' car, developed a servo unit utilizing the vacuum in the induction manifold of the petrol engine. This patent was taken over shortly afterwards by the Clayton Dewandre Co. Ltd., and became almost a world standard method for assisted braking and is still the most popular system for light and medium commercial vehicles. The addition of front wheel brakes followed directly on the heels of servo assistance and then, by 1930, four-wheel braking had become a recognized standard on all vehicles. Perrot in France and Pratt in England devised a shoe mechanism which gave a self-servo action by virtue of the friction characteristics of the shoe. This led to hydraulic actuation of the shoes, since the servo mechanism could readily be attached to the hydraulic master cylinder, and the combination thus provided a light and effective foot-braking system.

With the introduction of the compression ignition engine, it was quickly seen that, if power assistance was required, there was much in favour of the provision of a small compressor, from which air could be supplied at 100 lb/in^2, as against about 12 lb/in^2 in the case of the vacuum system. Further, the employment of air pressure made it possible to apply the actuating cylinders or diaphragms directly on to the road wheels. This latter system is predominant for heavy commercial vehicle brakes at the present day.

Structures

Again, in reviewing historical development, it can be said that the conception of the simple channel section frame structure to carry the requisite body or passenger loads has persisted throughout. Originally, timber with metal flitches had been used in many cases, and this was followed by simple rolled channel- or I-sections. Other manufacturers were early in developing the hot pressing of channel members. This method readily lent itself to the adoption of frames specially designed for passenger vehicles. These were arranged to provide the best distribution of material, with the requisite upsweeps over the axles so that a low floor level could be obtained. The reason why the original approach to a frame structure has remained so little altered is that it has proved capable of carrying the requisite payload without failure; moreover, on account of the facility with which the wheelbase can be altered and various types of attachments can be added, it is most suitable for trucks.

In the case of the public service vehicle, many attempts have been made to dispense with the frame as a separate unit and to attach power units and running components to an integral structure, the object being weight reduction. This form of construction has had considerable success in America and on the Continent. It, however, calls for a virtually standardized design of bodywork in order to permit the employment of jigs, pressings and assembly processes necessary to make it an economical proposition. The L.T.E. double-deck Routemaster, Fig. 13, with a light alloy structure designed on sound engineering principles, is an example of the use of an integral body. Another is the Leyland-M.C.W. single-deck Olympic, basically of all-steel construction.

Ancillary equipment

On the subject of engineering development of commercial vehicles, with the possible exception of electrical equipment, little need be added to what has already been mentioned concerning the primary components. Attention has been mainly directed towards the provision of adequate fully

Fig. 15. The Thornycroft Antar 6 × 4 tractor for cross-country operation. It has a Rolls-Royce 300 b.h.p. turbocharged power unit, a four-speed main gearbox, used in conjunction with a three-speed auxiliary box, and a double-reduction rear axle of the overhead worm and hub reduction layout. This vehicle can haul a total load of 224,000 lb

controllable illumination for night driving, and of reliable minor items such as screen wipers, cab heating systems and, in the case of public service vehicles, adequate interior heating, ventilation and lighting. In the early days oil lamps were used, and then came acetylene. At the beginning of the period under review, however, the simple generator, belt driven from the propeller shaft, was introduced and an associated development was the constant voltage control, which now permits generators of up to $1\frac{1}{2}$ kW to be used where needed. Ancillary equipment has never lagged behind development of the vehicle itself, and these two sections of the automobile industry have worked in the closest accord from the very early days.

The vehicle itself

Having briefly outlined unit development throughout the period under review I find it interesting to look back and see how these various units have been combined to meet differing requirements from time to time. Development has not been revolutionary: rather has it been a gradual evolution to meet changing conditions. The mounting of the engine at the front was adopted as the standard layout by nearly all makers of petrol driven vehicles—albeit cars were not necessarily so treated—and it is interesting to note how certain elementary features have been retained throughout. One example of an arrangement still in use is the employment of a simple bonnet housing the engine, with the driver situated behind a dashboard. At about the beginning of this period, however, it could be seen that, by mounting the driver alongside the engine, a considerable saving could be achieved in respect of space; this forward control was probably the most marked divergence from the earlier type of layout and has proved a popular alternative to the bonneted engine arrangement, or normal control.

In the early 1940s, Sentinel introduced an underfloor-engined truck, with the objective of reducing noise in the driver's cab, and also to provide a full width cab for driver and mate. This arrangement, nevertheless, has its limitations and has proved difficult where short wheelbases and tipping gear are required. In smaller units, however, Albion and Dennis have produced a medium weight underfloor-engined chassis having a low entry and full width cab, popular with door-to-door delivery companies. From the trends throughout the period, it does not appear that any major redisposition of the power unit is likely to be made for trucks.

In addition to the multi-axle rigid vehicle, Fig. 14, a further interesting introduction in the period has been the demountable semi-trailer. This, used in conjunction with a small tractor vehicle, such as the Scammell Horse or the Karrier Cob, has permitted the larger highway tractor to be used more economically: the semi-trailers are marshalled at the loading bays by small units whilst the heavy tractor unit is in full operation on the roads.

World War II presented an exercise in logistics for mobile warfare on a global basis; a consequence was the rapid development of special purpose vehicles. Examples of this development are too numerous to mention. Subsequently, marked progress has been made in special purpose cross-country trucks for oil exploration work and general development in backward areas. It is interesting to note that in the middle 1930s an eight-wheel drive, eight-wheel steering, road train vehicle was developed under Government ægis for cross-country use. These very special exploration trucks call for engines with high power outputs, of the order of 250 b.h.p, transmissions with an extremely wide range, generally some form of planetary transmission either alone or in combination with torque converters, large tyres for flotation purposes, and ease of control by virtue of power steering. Examples include the Scammell Constructor, the Thornycroft Antar, Fig. 15, and the Atkinson Omega. It is safe to claim that without this development in the heavy truck field, constructional achievements all over the world could never have made such strides.

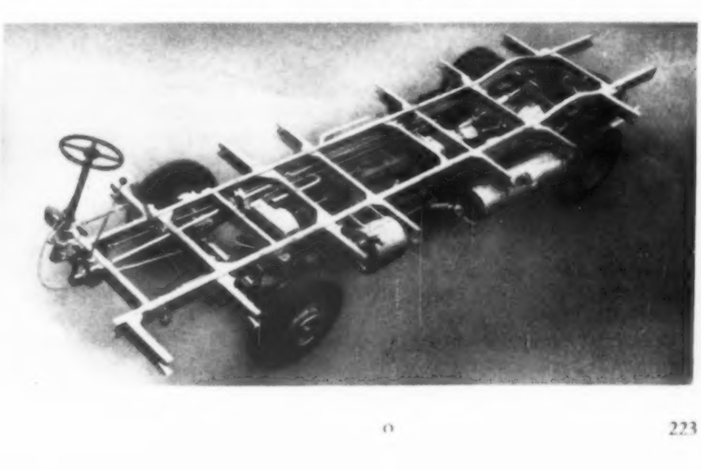
Summary

I have dealt primarily with the goods-carrying section of our business, and short references only have been made to the basic types of passenger vehicles that have been developed over the period. A great deal could be written, and in much detail, of this specialized field of transport, but I feel that the truck itself provides the major problem from which most new development springs. I would like, nevertheless, to draw the reader's attention to a few of the particular features that are to be seen mainly in passenger vehicles. Engines have been sited and used in almost every position in the chassis, and even today, buses with engines at the front, under the floor, Fig. 16, and at the rear, Fig. 17, are commonplace and in everyday use.

There cannot be a recognized standard for all purposes. Consideration must always be given to the conditions of operation and the special requirements of the different operators. The following features, nevertheless, have been proved desirable in all cases, and are insisted upon where possible. First, the safety and comfort of passengers whilst riding in, entering or leaving the vehicle is most important, and in comfort I include quietness of operation, adequacy of power and braking, and comfort of springing. Secondly, and scarcely less significant to the operator, are ease of

Fig. 17. The rear-engined Atlantean has a compact power unit installation that can be removed, for servicing, in a few minutes. It has a transmission system that includes a centrifugal clutch, a Wilson type four-speed gearbox and an angled drive to the extreme right end of the rear axle, and the saloon is well isolated from noise

Fig. 16. The underfloor-engined chassis illustrated below was introduced by Leyland in 1948. It provides a body of maximum seating capacity without any projections above the floor. The engine is a six-cylinder 125 b.h.p. diesel unit, and it is used in conjunction with a single-dry-plate clutch and a four-speed synchromesh gearbox



driving, comfort and safety from the driver's angle and, finally, the best arrangement to provide quick on- and off-loading of passengers during peak periods and with adequate control by a conductor. This subject is a profound one and for adequate treatment would need a paper of its own.

I have found some difficulty in presenting a reasonably clear engineering review of development over the last fifty years in this relatively short article. I have, however, tried to outline broadly the whole of the development as centred round the units themselves, and then the combination of such units as they have been used in their various forms in the completed vehicle. Today's design not only provides for the benefit of the operator the best that is known, but also a high degree of flexibility for production purposes. Units must be employed in what we know as the Meccano system, in which a combination of the minimum number of basic components can be used to build up the greatest variety of completed vehicles.

The commercial vehicle industry, by virtue of its use of such highly developed and economic units, has become closely associated with applications other than road vehicles, in particular earth-movers and stationary power plants. The rapid extension of trunk roads at home and abroad has demanded such equipment in ever increasing numbers. This trend was hardly foreseen in the early days of the period, but latterly the contribution which the commercial vehicle has been able to make to this phase of development has become apparent.

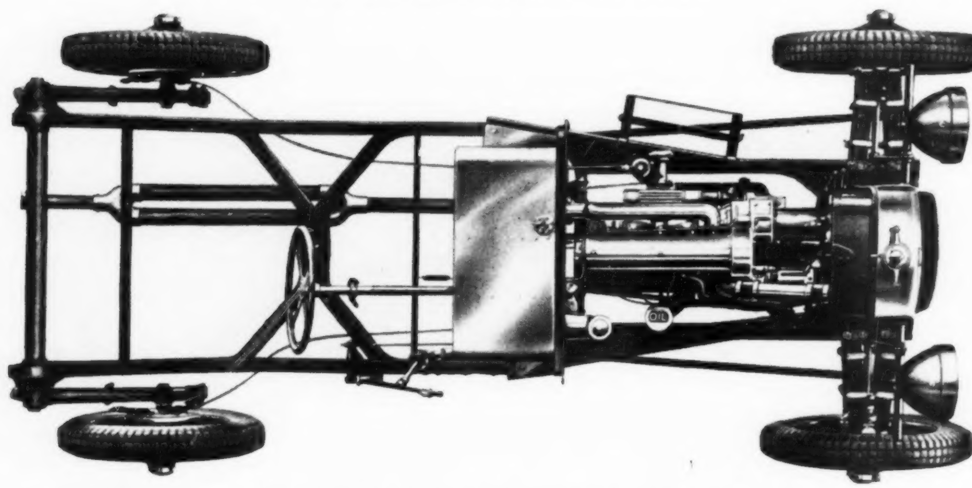
At the turn of the century, the steam locomotive was predominant for all forms of rail transportation, but in recent years there has been a definite switch to diesel power, and new equipment in British Railways includes many multi-engined diesel railcar units. Some of these are equipped with bus type power units, of between 150 and 250 b.h.p, specially adapted to meet the requirements of that service and providing, incidentally, the means of making an economic proposition once again, many branch lines that hitherto had been faced with the possibility of closing down.

I feel that evolution rather than revolution has been the keynote of development in our industry, and almost certainly it will continue on those lines. The road is a pre-requisite for vehicle use; nevertheless, special vehicles provide the facility for transport of the materials of construction before the roads are made. Therefore, the scope for vehicles in world progress is tremendous. Modern techniques in design and manufacture, coupled with intensive technical education and improved training facilities will, I feel sure, result in continued leadership of the U.K. in this field.

Evolution of the Car Chassis

A Review of the Development of Frames, Suspension, Brakes and Transmission Systems

G. H. LANCHESTER, M.I.Mech.E., M.S.A.E.



The 1926 Alvis front-wheel-drive chassis had independent suspension, with quarter-elliptic springs, on all four wheels

To trace in detail the past fifty years of evolution encompassed by the heading is outside the scope of this article, and to study and evaluate every individual design and innovation would involve a protracted search through historic and technical publications; moreover, much detail has regrettably been lost. It is intended, therefore, to give only a broad outline of evolution covering the generality of types that, by reason of their wide acceptance, have attained some measure of uniformity.

Chassis frames

Before the turn of the century, no uniformity of design existed. There was no precedent for guidance of the pioneer designers, and so each put his own ideas into practice. Basically, there were two schools of thought: one based on traditional coach engineering and the other on cycle engineering. Broadly speaking, the former was applied to cars of the heavier type—those with four or more seats; cycle engineering, on the other hand, was mostly favoured for light cars with two or three seats.

The chassis frames following coachbuilding tradition consisted of timber side and transverse members, with steel flitch plates and steel gussets at the junctions between them. Combinations of timber—generally ash—and steel were prevalent during the first decade of the twentieth century and, in a few instances, persisted until after the 1914-18 war.

The earliest steel channel frames consisted of plain cold-rolled parallel sections, and some were reinforced with struts and tie-rods to form more uniformly stressed beam structures. As in the case of the timber frames, the cross members were reinforced with steel gussets at their junction with the side channels, the joints being effected by hot riveting or with bolts and nuts.

It was not until about 1903 that the technique of manufacturing steel channels by pressing sheet material began to be exploited, the earliest examples being the Darracq and Canstatt-Daimler (Mercedes) frames, closely followed by the introduction of similar types by Austin. The commercial success of this development depended on the progress in the design and construction of heavy power presses. It is of interest that, from the outset, torsional stiffness was a feature of Lanchester cars, and that the Lanchester design represented a 'law unto itself'; however, this will be dealt with in more detail later.

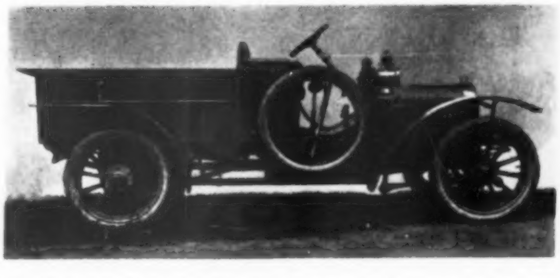
The majority of automobile engineers of that period argued that a flexible chassis frame was advantageous since it supplemented the suspension system. But flexibility in the chassis frame made it necessary to interpose a universally jointed coupling-shaft between the engine and gearbox—which in those days was mounted separately—thereby increasing the number of components, and the weight and space occupied by mechanism; it also, of course, increased cost. To avoid these undesirable features, the engine and gearbox were in many instances mounted on a sub-frame, which served to minimize the effects of distortion of the main frame and consequent misalignment of the mechanism.

Not until towards the end of the first decade of the twentieth century was there any semblance of uniformity in design leading to what could be termed an orthodox type. The first evidence of the emergence of any degree of uniformity was the general acceptance of the front end installation of the engine. This no doubt can be attributed to the fact that engines of that period required frequent attention and it was desirable, therefore, to have them in the most accessible position.

A milestone in the development of chassis construction was the introduction of autogenous welding in place of hot riveting or bolts and nuts. Oxy-acetylene welding was introduced by Allen-Liversidge in about 1913, and they also marketed equipment for this process; however, owing to the difficulty of preventing distortion, it made little progress. In fact, welding was not taken seriously until the early 1920s, when the processes of electric welding—arc, spot, and flash welding—were developed on a commercial scale. Many technical difficulties had to be overcome, the greatest being that of preventing the deterioration of the metal by oxidation in the vicinity of the weld. The latter problem was overcome by coating the electrode wire with a chemical producing an inert, or non-oxidizing, atmosphere in an area surrounding the arc. Today, one of the latest methods—which was discussed in the March 1960 issue of *Automobile Engineer*—is to feed the welding electrode through a jet of carbon dioxide. During the years 1920 to 1930 electric welding made rapid progress, and was applied to almost every major component of the chassis, including the Rubery Owen steel wheels. By the 1930s bolts and rivets were no longer to be seen on the frames of quantity produced cars.

Torsional rigidity, previously mentioned, began to be generally recognised in about 1909 or 1910, but was not accepted as being of paramount importance until the introduction of low-pressure tyres and front wheel brakes, in the early 1920s. The introduction of these two features, which occurred concurrently, combined to cause serious steering troubles.

Hitherto, shimmy and tramp were rarely experienced—and even when they were, they usually occurred only at speeds above that at which the majority drove—but with the introduction of low-pressure tyres and front wheel brakes there came an epidemic of these troubles. Low-pressure tyres led to a lower wheel-hop frequency; and the added weight of brakes at the extremities of the axle beam increased the moment of inertia of that assembly, and therefore also reduced its natural frequency of oscillation about its geometric centre. As a result of this combination of circumstances, the front wheels tended to rise and fall alternately—the phenomenon known as tramp—at speeds well below the maximum at which the majority of users drove. This angular motion gave rise to a gyroscopic torque on the front wheels, which was transmitted back to the steering wheel. So violent was this oscillation that it was impossible to hold the wheel steady and, to many drivers it was terrifying to experience high-speed tramp.



The shooting brake, or station wagon, is currently becoming increasingly popular; however, it is not new, for this Vauxhall model with an open body of timber construction was in production in 1910, and there were even earlier examples with both closed and open types of body

At first, various palliatives were applied to deal with this problem. One was the employment of a tubular cross member, in some instances with diagonal bracing from the tube to the dumb-irons, to stiffen the front end of the chassis frame. Another was the use of a kick shackle, which allowed some fore-and-aft movement of the front spring on the side adjacent to the steering box; this movement was regulated by stiff springs. Measures such as increasing the stiffness of the front springs and the friction in the steering mechanism were also employed with some degree of success, but with detrimental effects so far as ease of driving was concerned.

It soon became apparent that fundamental research was necessary, and that the ultimate remedy lay in the adoption of independent suspension of the front wheels. An outstanding example of independent suspension was that of the Lancia Lambda of 1921, which was continued as an individual feature of Lancia cars for many years. However, even then, independent springing was not a new invention: other examples existed in this country—Stephens, 1898, and Parnacott, 1912. These designs came before their time and failed to be developed, as the need for them was not pressing.

Torsional rigidity of chassis frames was attained by two methods. One was the employment of the ladder type chassis, in which tubular cross members were substituted for the channel pressings used hitherto, and the width and depth of the side members were increased. The second was the introduction of the cruciform cross member.

Cruciform construction is based on the principle that a tetrahedron is the only basic geometric form, other than the tube, that is inherently torsionally rigid. By placing two such structures together, having the vertical component common to both, we get the equivalent of the cruciform frame. Substitution of an open-ended box-like element for the centre pillar, to accommodate the propeller shaft, need not materially affect the strength or stiffness of the assembly. It is, of course, obvious that the extremities of the cruciform should join the side members in the vicinity

of the suspension anchorages or as near to these points as possible.

The two types of chassis frame just described were almost universally employed until the era of the chassisless car which, since World War II, has superseded the frame so far as European cars were concerned. However, there were two other types of chassis frame worthy of mention. One is the tubular backbone type, with outriggers to support the body—an early example of this is the 8 h.p. Rover, and later examples are the Tatra and the Triumph Herald. This type of construction possesses good features, particularly with regard to torsional stiffness, and it is therefore surprising that it is not more popular since, in respect of weight and cost, it can compare favourably with the more orthodox designs. The second noteworthy type of frame is that in which box section side members are employed instead of channel pressings. This type was initiated by Lanchester in 1904 and employed in their 20 to 28 h.p. cars from 1904 to 1911. It possesses good torsional stiffness and need be no heavier than the orthodox pressed steel channel frame. The box section frame was adopted by a few manufacturers in the early 1930s but had a relatively brief period of popularity in Europe. It was expensive to produce and had technical disadvantages, not the least of which was resonance, which was difficult both to locate and to suppress.

Eliminating the chassis frame

During the late 1940s and early 1950s, chassisless cars became predominant, so that today the car with a separate frame is almost obsolete in Europe. In the early stage of development some designs incorporated the body as an integral unit built on a sub-frame; this sub-frame, which in at least one instance was an assembly of aluminium castings, formed the foundation on which were mounted the power plant and suspension. In the later stage of evolution, however, much ingenuity was put into the design of pressed steel bodies, with the object of rendering them torsionally stiff and reinforcing them adequately to support the engine and gearbox unit and the other mechanical components.

This development has been made possible only by production in large numbers of relatively few types of bodies. Although the chassisless car has won for itself a considerable degree of success, it is the author's opinion that it is a retrograde step, and there are indications of a reversion to some form of independent chassis frame. In the United States, most of the automobile manufacturers have of course retained the separate frame type of layout for both private cars and light commercial vehicles based on the same chassis.

A disadvantage of the chassisless car is that there is no way of insulating the body from resonant vibrations transmitted from the road by the undamped impacts of the tyres. This causes body drumming, which is a source of discomfort. On the other hand, the chassisless car has justified its existence by virtue of its performance and lower cost of production.

Suspension

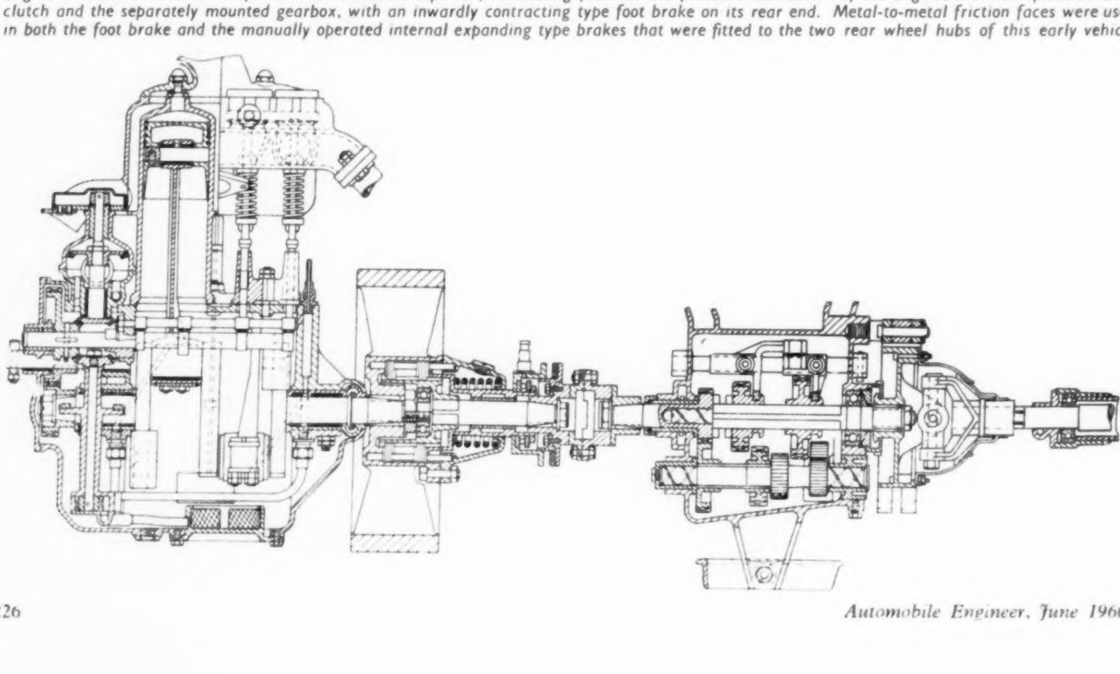
Before 1900, the types of spring systems employed were many and various. For the most part, designers based suspension systems on traditional practice of horse drawn vehicles. We find many examples of full elliptic springs; where half elliptic springs—another popular type—were employed, they were deeply cambered, following horse drawn vehicle practice. These layouts were soon found to give insufficient stability both in a fore-and-aft direction and laterally.

During the early years of the present century, designs rapidly settled down to more rational types. The outstanding one, which became almost universally adopted, was the Hotchkiss. It has the merit of simplicity, while being geometrically and dynamically sound. Subsequently, this layout was challenged only by the independent suspension layout. In fact, so far as the front end is concerned, independent suspension not only challenged but of course superseded the Hotchkiss layout on the vast majority of private cars.

A feature of the Hotchkiss suspension was the employment of relatively long springs, with practically no camber under load, and so positioned that the motions of the suspension components were in harmony with that of the propeller shaft at the rear and of the steering link at the front. There were, of course, other successful types of suspension, such as cantilever springs, on some of the largest and high grade cars, and quarter elliptic on many cars of the voiturette and cycle-car classes.

Of independent suspension systems there are many

Engine and transmission unit of the 1910 Humber 8 h.p. car; interesting features are pressure lubrication of the engine, the multi-plate oil-bath clutch and the separately mounted gearbox, with an inwardly contracting type foot brake on its rear end. Metal-to-metal friction faces were used in both the foot brake and the manually operated internal expanding type brakes that were fitted to the two rear wheel hubs of this early vehicle

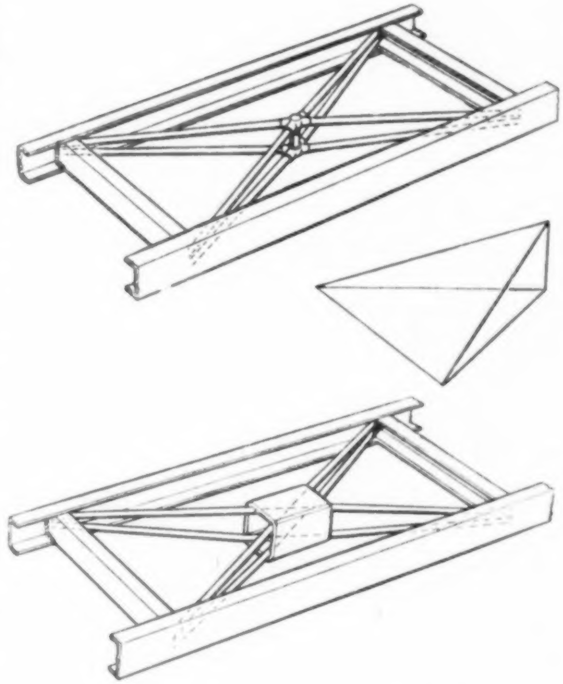


variations, but the most successful—those that have survived what might be described as the probationary period—are the transverse wishbone link type in combination with coil or torsion bar springs, and the trailing arm type with torsion bar springs. Of these, the wishbone layout has a clear majority of exponents. In both types the motion of the front wheels is confined to a vertical or near vertical plane throughout the whole range, and hence there is no gyroscopic torque.

As indicated under the heading Chassis Frames, independent suspension became generally accepted in the 1920s. It has gained in popularity steadily until, today, there are few cars that are not so equipped, and in many instances an independent system is also applied to the rear wheels.

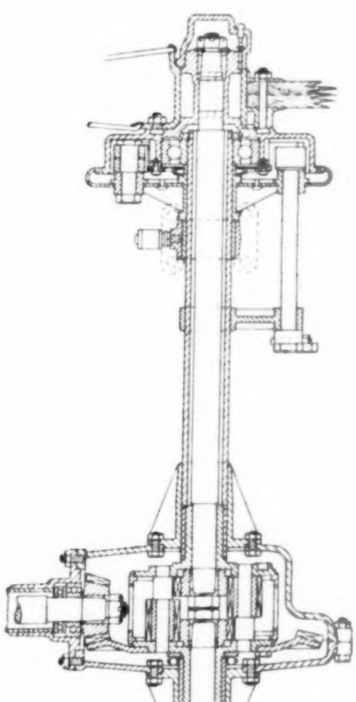
On cars of Continental origin, independent suspension of the articulated half-axle layout is popular. Examples of this type, which in pre-war days was peculiar to one or two cars of Czechoslovakian manufacture, are now seen on well known vehicles manufactured in France and Germany. However, it does not appear to be likely to become more popular in this country.

For racing cars of light weight, the rear axle suspension is commonly of the parallel trailing link type, as used by Lanchester at the commencement of the period under review, but in combination with more modern spring systems and shock damping devices. Finally, all-rubber suspension was tried experimentally and its application described by Colin Macbeth in a paper "Rubber and Automobiles", delivered in 1933 to the Institution of the Rubber Industry.



These diagrams show the fundamental principle of combining two tetrahedrons, the simplest basic geometric form that has torsional stiffness, to form a cruciform bracing. The tetrahedron is illustrated in the centre, an elementary cruciform structure above it and a similar structure, but with a propeller shaft tunnel, is shown in the lower diagram

Below: Final drive of the engine and transmission illustrated on the left. This Humber vehicle had detachable, wooden spoke artillery type wheels, or wire wheels as alternatives, and 750 × 85 mm (30 × 3¼ in) Dunlop tyres were specified. Another interesting feature is the straight bevel reduction in conjunction with a spur gear differential unit



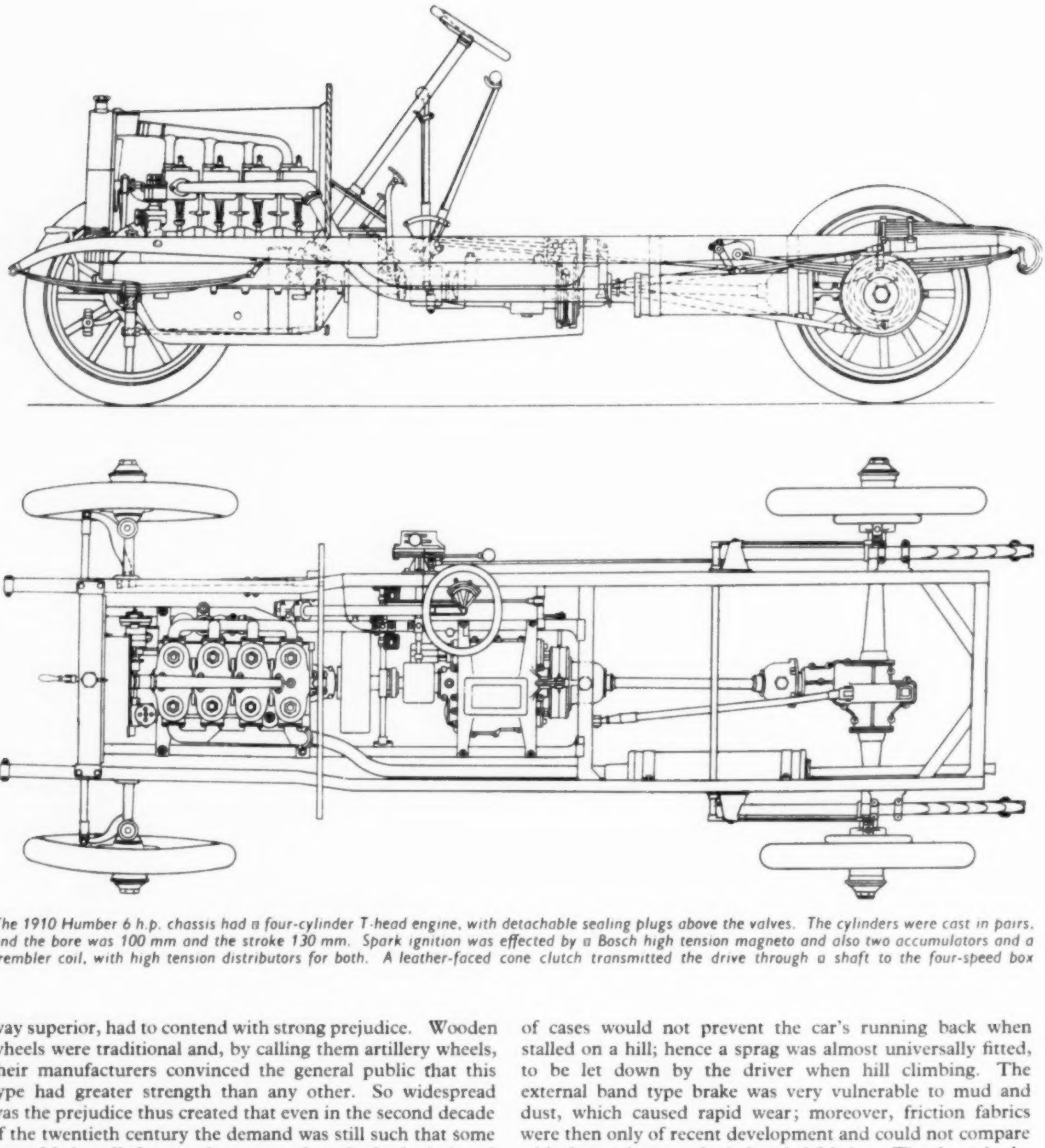
Since World War II, one large British operator of public service vehicles has developed a successful all-rubber suspension for its passenger coaches, and a car manufacturer has adopted another two systems, one for a very small car and the other for a cross country vehicle. With the ever increasing improvements in physical and chemical properties and durability of rubbers, there is a prospect, of primary importance, of rubber springs superseding the more expensive, but hitherto essential, steel ones for suspension.

Other specialised types of suspension include the hydropneumatic systems, developed during the late war and without doubt contributed to by the employment of hydropneumatic devices on aircraft. The Citroën suspension, on their DS and ID cars, is the outstanding example. To what extent this type of system will become more widely accepted depends largely on freedom from maintenance troubles. In fact, this system appears to be some years distant, as also are the rubber suspension spring systems. No mention has been made of air suspension, since no car manufacturer in Europe has yet adopted it as standard equipment.

Wheels

Although some of the earliest Continental cars were equipped with wire spoke wheels—for example, Benz in 1889 and the Leon Bollée three-wheeler—some of the early British manufacturers, from 1895 onwards adopted similar practice but in an improved form. These British wheels were constructed on the tangent spoke principle, borrowed from the most advanced cycle practice of the period. The majority, however, both at home and abroad, used wooden wheels based on the old coach practice.

Wire spoke wheels, while being stronger and lighter than wooden ones and, from an engineering standpoint, in every



The 1910 Humber 6 h.p. chassis had a four-cylinder T-head engine, with detachable sealing plugs above the valves. The cylinders were cast in pairs, and the bore was 100 mm and the stroke 130 mm. Spark ignition was effected by a Bosch high tension magneto and also two accumulators and a trembler coil, with high tension distributors for both. A leather-faced cone clutch transmitted the drive through a shaft to the four-speed box

way superior, had to contend with strong prejudice. Wooden wheels were traditional and, by calling them artillery wheels, their manufacturers convinced the general public that this type had greater strength than any other. So widespread was the prejudice thus created that even in the second decade of the twentieth century the demand was still such that some firms felt impelled to produce pressed steel wheels designed to imitate the coachbuilt variety. This type attained a considerable degree of popularity in spite of the fact that they were heavier than wire wheels. However, most of the high quality cars, such as Rolls-Royce, Daimler, Lanchester and Napier, pinned their faith on wire wheels, and fitted alternatives only on customers' demand. On the score of economics, the pressed steel wheel, which made its emergence in the early 1930s, has virtually ousted the wire wheel except on some sports cars and most racing models.

Brakes

In the majority of cars in the years 1900 to 1910 external band brakes were employed. The designs were such as to provide an element of self wrapping when operating with the vehicle moving in a forward direction. In reverse, however, the brake was self unwrapping, and in the majority of cases would not prevent the car's running back when stalled on a hill; hence a sprag was almost universally fitted, to be let down by the driver when hill climbing. The external band type brake was very vulnerable to mud and dust, which caused rapid wear; moreover, friction fabrics were then only of recent development and could not compare with the modern synthetic bonded fabrics. The drum brake with simple internal caliper shoes was a marked advance, only to be superseded by brakes with various forms of self energizing shoes.

Disc brakes were first introduced on a motor vehicle in 1903, which was before friction fabrics, so copper brake pads were used. Since these pads were exposed to mud and dust, as were the external bands, they wore out very rapidly and this type was abandoned. Now, by virtue of modern materials and techniques, disc brakes have shown a marked advantage over the drum types. Although either can be made to give stopping power far beyond that which the passengers can tolerate comfortably, the disc brake gives more consistent performance and is not subject to distortion and fading on long declivities.

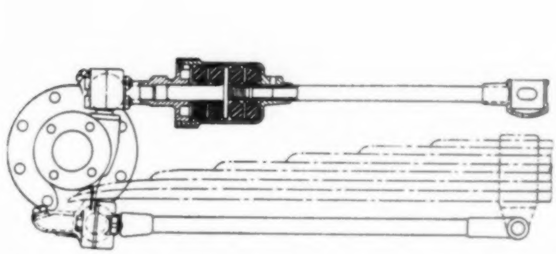
Prior to the introduction of friction fabrics, brakes were lined either with leather or copper segments. It was cus-

tomary to dress leather with resin, to improve its frictional properties. Two important landmarks in the evolution of brakes and brake mechanism were the introduction of the pneumatic servo system and hydraulic brake actuation. The vacuum servos of Clayton Dewandre and Westinghouse were principally used. These came into being immediately after the 1914-18 war. Hydraulic brake actuation obviated mechanical links and their numerous pin-and-clevis joints which, if not given frequent attention, were a source of rattle and squeaks.

Transmission

In the opening years of the twentieth century the majority of cars were chain driven. The half-shafts and differential gears were incorporated in the gearbox, the sprocket pinions being mounted on the outer ends of the half-shafts. The sprocket wheels, bolted to the road wheels, were mounted on an axle-tree, or dead axle.

During the first ten years of the century chain drives were gradually replaced by propeller shafts—Lanchester 1900, Decauville 1902—and by 1910, chain drives were the exception rather than the rule. Then the half-shafts and differential were transferred to a rear axle unit, in which was incorporated a gear drive. In most instances, this drive was a live axle, with a straight-tooth bevel gear and differential gears, and was encased in an oil bath housing. Some manufacturers, however, employed worm gears, owing to their superiority in respect of silence, for rear axles. At the extremities of the housing were brackets, or spring beds, for suspension mounting. This layout was virtually standard



In 1910 the 20 h.p. Lanchester front and rear axles were located by radius rods. The semi-elliptic springs were partly enclosed by the frame members, one end of each passing through a slot in the axle pad

practice until the evolution of the independent suspension.

As the years went by, the straight-tooth bevel gear, because of the difficulty of making it silent, was superseded by the spiral-tooth type, which, in turn, was followed by the hypoid bevel because it permitted a lower floor level, an advantage hitherto offered solely by the worm gear. The hypoid bevel is on practically equal terms with the worm so far as silence is concerned, but has the advantage of lower cost.

In some designs, the propeller shaft was enclosed in a torque tube having a trunnion joint coincident with the universal joint on the output shaft of the gearbox, while others had a hollow sphere freely mounted in a spherical socket concentric with the universal joint and secured to the rear face of the gearbox. The former of these two methods was characteristic of the Hotchkiss suspension in which the springs themselves located the rear axle.

Gearboxes

At the beginning of the twentieth century there were gearboxes of many types, differently located, and a variety of gear change systems and different layouts of change mechanism. Moreover, several gear tooth forms were current, and the various gear cluster arrangements added even more variety to the scene. But by the end of the first decade, designs had settled down, more or less to a standard layout, and manufacturers were beginning to concentrate on production problems rather than exploiting new designs. At this time component specialists were springing up and were manufacturing ranges of standardized equipment such as complete rear axles, front axle assemblies and steering mechanisms. Car manufacturers were looking to either their own subsidiary firms or outside specialists for the supply of components, so that they could increase their output of vehicles without involving themselves in heavy capital expenditure.

The period of 1910 to 1930 might be termed one of consolidation in the motor industry when, except for much needed improvements such as synchromesh gear change, further evolution in design had to give place to evolution in production methods. This process continued until interrupted by World War II. Then, for the first few years of so-called peace, designs remained much as they were before the war. This was inevitable for economic reasons. After this there began a new period of design evolution in which were developed automatic transmission systems with hydraulic torque converters, automatically controlled mechanical systems, with hydraulic or electrical controls, and revised ideas in respect of the optimum disposition of engine and gearbox. At the same time, parallel developments were taking place in the wide exploitation of chassisless construction and independent suspension for front and rear wheels, advanced technique in brakes and brake mechanisms; also, new materials and methods brought disc brakes very much to the fore.

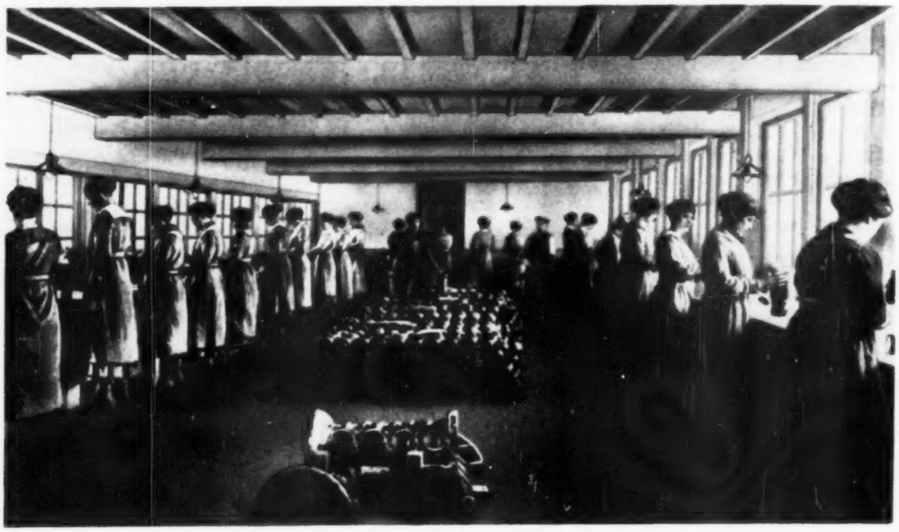
From these facts one can deduce that the industry is now going through another period of evolution in which advantages and disadvantages will have to be weighed and tested by experience before it settles down to another period of stability. In production, too, great changes are in the process of development, one being the rapid growth of automation, and full advantage of this can be taken only when designs become stabilized once again.

Epilogue

In the foregoing the author has of necessity generalized. There were and still are many exceptions to the normal, both in design and layout, and the author feels that it is not inappropriate to give an illustration of some of the exceptional cases with which he has had lifelong experience, that is, in connection with the cars evolved and designed by Dr. F. W. Lanchester, a man of unique and original thought.

From the commencement, the Lanchester designs, of which the following features are only a few examples, were outstanding in many respects. Torsional stiffness of the chassis was inherent in all Lanchester designs from 1895 to 1931. Mechanically operated inlet valves were introduced in 1895, as also were epicyclic gears, live axles and wire spoke wheels. A high efficiency silent worm gear drive, roller bearings and splined shafts and broached holes were adopted in 1897. Cantilever suspension was employed on all Lanchester designs from 1897 to 1931. The year 1900 saw the adoption by this company of a propeller shaft drive, and the engine and gearbox as one assembly. Metal-to-metal clutch and brake friction faces were employed in 1901.

All his models introduced in 1940 had overhead valves and high pressure lubrication, and the engine and gearbox unit was similar in layout to that now widely employed. Another interesting feature was the forward control layout, with the engine between the driver and passenger, introduced in 1904. This was abandoned in 1917, but is now widely used in the public service and commercial vehicles.



This view of the valve grinding-in room at Maidstone during World War I, shows the complete absence of mechanical aids to production in those days

A Lifetime in Automobile Production

A Short Survey of the Major Factors that have Influenced the Trends of Development Over the Last Fifty Years

E. W. HANCOCK, O.B.E., M.I.Mech.E., Hon. M.I.P.E., F.R.S.A.*

FIFTY years ago, as a schoolboy, I was seriously considering engineering with a view to taking it up as a career, and in 1911 took the plunge and started as an apprentice with the Vauxhall and West Hydraulic Co. Ltd., Luton, Bedfordshire. This firm, which was an offspring of the Vauxhall Ironworks, London, was situated in the middle of the fields, the only other building in sight being a farmhouse. Over the brow of the hill was a small works, then known as the Vauxhall Motors, which also was an offspring from London.

In this setting, production engineering was of course very different from today. We apprentices walked to the factory, started work at 6 a.m. and finished at 5 p.m. On top of this, we had three evenings per week at what we called "night school". Individual initiative was essential for survival: primarily, initiative was needed to discover right from wrong and to pick workmates who were skilled in their craft and willing to teach a young and rather small boy like myself the basic principles of production, such as the names and uses of tools, the feel of a surface or of a fit of one part to another. My first introduction to production was in the tool stores, where very early in life I learnt many things: I soon discovered that while a request for a left-handed spanner was a leg-pull, if I was asked for a pair of footprints I was expected literally to jump to it and produce the real tool. But even now, retiring this month after a lifetime in production engineering, I still wish I knew all the answers.

In those days machines were virtually used as roughing out tools for removing the main weight of surplus material from very rough castings or solid forgings. The finishing tools were those manipulated by hand: after the hacksaw and hammer and chisel had been used, the final operations were done with the file and scraper.

So far as the skilled workers were concerned, the marker off was the key man, since the success of the job depended primarily on his interpretation of the drawing, and one of the heights of an apprentice's ambition then was to go on the marking off table.

Each part was individually marked off and scribed lines and centre punch dots were the guide to the machinist. First, the castings and forgings were *favoured* by the marker off, to determine the *best average* of the casting or forging; in fact it frequently was only the skill of the marker off that saved scrapping a valuable casting or forging. If there were more than one of an individual part to be marked off, an accurate template, usually of sheet steel, was made; these templates were treasured possessions of the marker off and were locked up or hidden for safety.

The machinist would set up his casting or forging to the lines and dots put on by the marker off and would always leave a *witness* of the line or a split dot to prove his exact interpretation of the marking off. When the fitter took over the machined parts, he had to decide his own datum point or line, from which he could work for his assembly: for example, in lining up crankcase bearings prior to hand scraping it was necessary to select which bearings he should scrape first to accept the test bar; of course, a five bearing crankcase presented a much more difficult task for ultimate accuracy than a three bearing case. Then the actual crankshaft that was to be fitted to the crankcase was offered up; the fitting of the one to the other took a long time, and it

*Director of Special Projects, Rootes Group, Manufacturing Division; Director, Humber Ltd.

was quite an event when the crankshaft was finally married to the crankcase. If the crankshaft could be turned by a lever less than 2 ft long, it was too slack for running in.

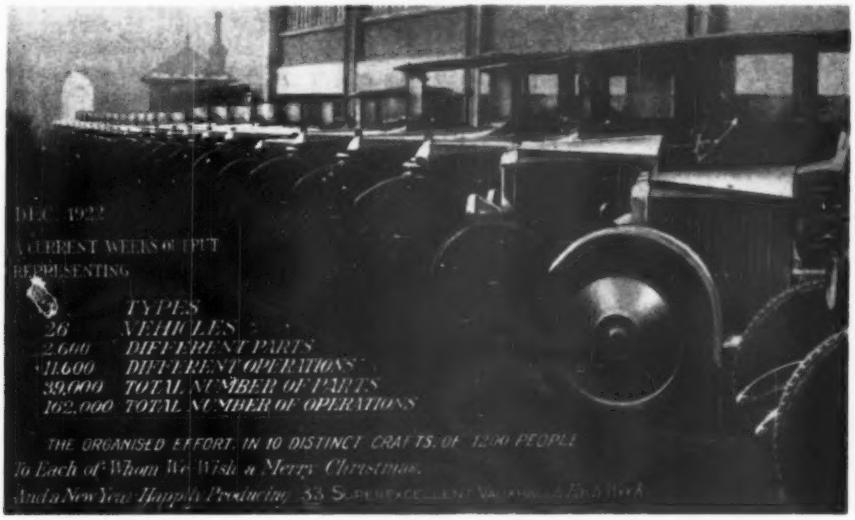
When the engine was eventually finished by the individual fitter, who in those days was usually held personally responsible for the complete assembly, it was passed to the engine test section, first for running in and a subsequent stripping down, final scraping and adjustment, and then for a preliminary power test. After this the unit would eventually be installed in a chassis, which finally was passed to the running shed.

Then, a further process of testing took place, mainly to run the chassis on the road so that certain units, according to the whim or the skill of the tester, could then be stripped, adjusted and re-tested. From the beginning to the end, that is from the fitter to the final tester, there was a gradual increase in the application of individual skills, re-adjusting, bedding-in and refining. Each car was individual and different, and none of the mechanical components was interchangeable, so they all had to be fitted very carefully. It was of course waiting for the day when the coachbuilder would complete his task and let the running shed staff take over once more, for the final test. How noisy had become the rear axle and the gearbox, how full of creaks and rattles the body! Once more the process of a new and peculiar skill in road testing gradually reduced these noises to an acceptable, or *as good as you can get it*, standard. Then the great day came and the car was demonstrated and handed over to the customer.

Overall Progress

In the machine shop, the first move towards mechanical repetition methods of production, and towards intrinsic accuracy, was the use of jigs and special tools, and new methods of measurement. This at least enabled selective assembly methods to be adopted. Then the use of limits of accuracy in the machine shop and the improved accuracy of machine tools gave the fitter a more consistent job to work on.

The kaleidoscope of change started before the World War I, when the marker off had moved back into the tool room, to mark off castings and forgings, for jigs, tools and gauges—by this time, the advent of planning engineers and the issue of process operation sheets led to the establishment of logical sequences of operations, although for some years the operation sheets were used only as a general guide. The fitter, with all his skills, files and scrapers, also moved back into the tool room. His beautifully made, hand scraped bearings were now used to carry the main spindles of machine tools capable of producing, by the thousand, components to the same degree of accuracy. Parts were being made interchangeable and were fitted to each other by measurement instead of by feel.



Reproduction of a Vauxhall Motors' Christmas card of 1922. It is of interest to compare the output then with details of the current production, figures for which are given on the following page of this article

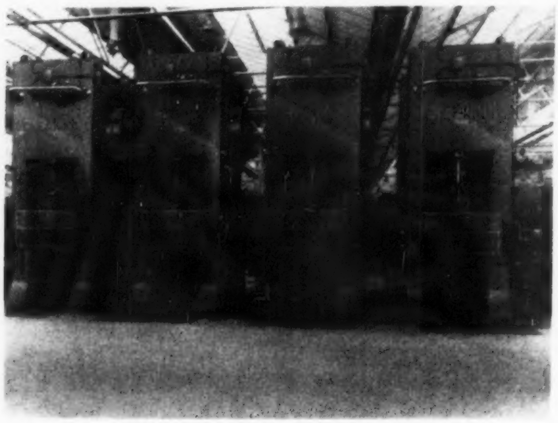
In those days one could pick out a good car for a special customer; it was necessary to bear in mind that he, or his chauffeur, was a mechanic at heart, if not in fact, and that each car had to satisfy different customers in different ways. Body shapes and sizes were fashioned to suit individual requirements, and the customer, who would visit the works from time to time to inspect the body, would often have alterations carried out during construction. These alterations could be effected relatively easily by the coachbuilder, who was individually responsible for the body.

It was customary for the car chassis to be driven to the coachbuilder for the body to be virtually tailored to it, the frame of the body being individually fitted and assembled on it. When the wooden framework was completed, the hand beaten sheet metal panels were pinned on—later this operation was one of the major causes of disagreement, on lines of demarcation, between trade unions. Finally, the bonnets and wings were made and fitted.

The chassis, which had been the pride of the road tester, was now standing covered with wood chippings, pieces of sharp jagged sheet metal and filings, and looking very untidy. It was of course waiting for the day when the coachbuilder

In World War I, the motor industry played a major part, not only in producing cars, trucks and tanks but also aero engines and aircraft. For example, a firm now in the Rootes Group made aero engines in World War I; an accompanying illustration shows their valve grinding-in room, in which this key operation on valves was done by female labour. Great strides were made by the production engineers of this country, and special requirements for the production of munitions gave them the opportunity to develop new

The illustration above is of a wheel maker putting the iron tyre on to a wooden spoke wheel in the factory of Paul I. Headley, who started to make wooden wheels about 1900. This firm still produces about 40 pairs per week, as against approximately 150 pairs per week forty years ago



Clearing transfer presses, installed at the Dunlop wheel factory in Coventry, for the production of the centres of modern vehicle wheels

techniques. One outcome was the ascendancy of the machine tool.

After the war the manufacturing techniques in respect of the mechanical components moved ahead much faster than those for the production of bodies: in fact, car bodies were still being made in much the same way as before the war. Gradually, however, new ideas were introduced: one body shop with which I was associated started to make the wooden body-members on jigs, and in batches, jig drilling one side of the half-joints. Assembly jigs were also used, so that all the wood frame members could be glued and held together and the wood screws driven in by a Yankee Brace; this made it possible to assemble the body unit in a separate shop, to consistent dimensions, for mounting on the chassis elsewhere. I even remember a paper on the fallacy of the use of jigs in body building being presented to a professional institution!

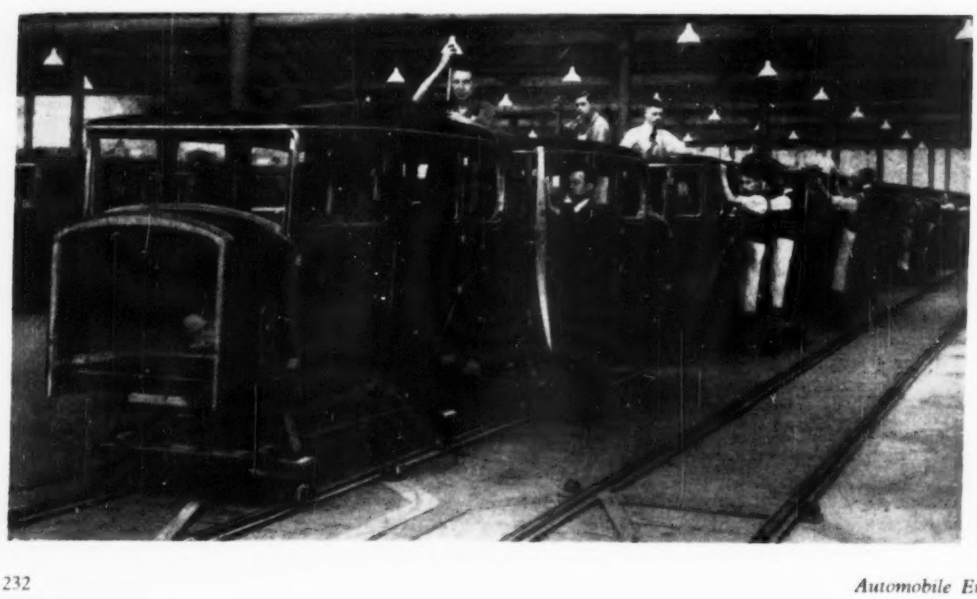
But gradually competition on the one hand and improved vehicle performance on the other made it necessary to give more attention to the body, which therefore came to be considered as part of the complete structure and not just an afterthought. Subsequently, progress was aimed at improved power : weight ratio and the body became a stressed structure. There was great excitement when the first all-steel body made its appearance, and I remember a car of this type being rolled over down a slope, and then driven away, to demonstrate its safety in the event of an accident.

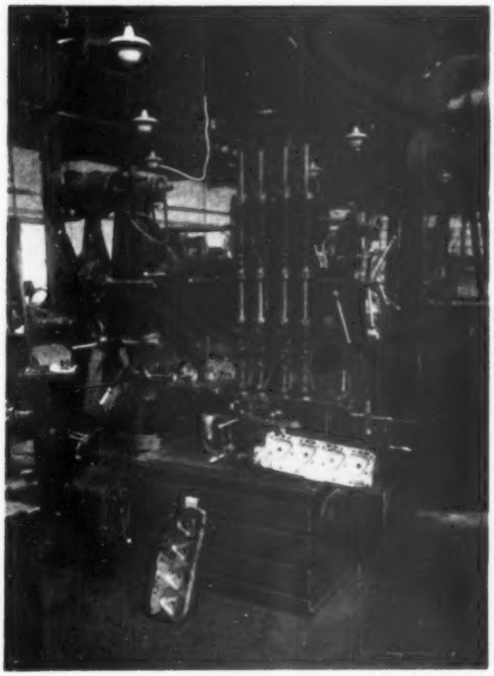
Expansion of production

With expansion schemes currently so much to the fore, it is of interest to look back at the Vauxhall Motors efforts shortly after World War I. The accompanying illustration of their Christmas card for that year shows one week's output of 26 cars, by 1,200 people—and no doubt this was a particularly good week. The expansion scheme projected for 1923, namely 33 cars per week, represented an increase of about 25 per cent. I well remember having to work out all the figures, such as the number of components and operations, and being appalled at their magnitude. Today, the weekly output, from 26,250 people, is in the order of 6,200 units per week—some of these units are c.k.d—and the projected expansion schemes include a 25 per cent increase of the 1,000,800 ft² at Dunstable and a factory at Ellesmere Port to give an additional 2,500,000 ft² of space.

It was during the period after World War I that we

Composite body shells, with timber frames and metal panels, being built on the production line at the Humber car factory





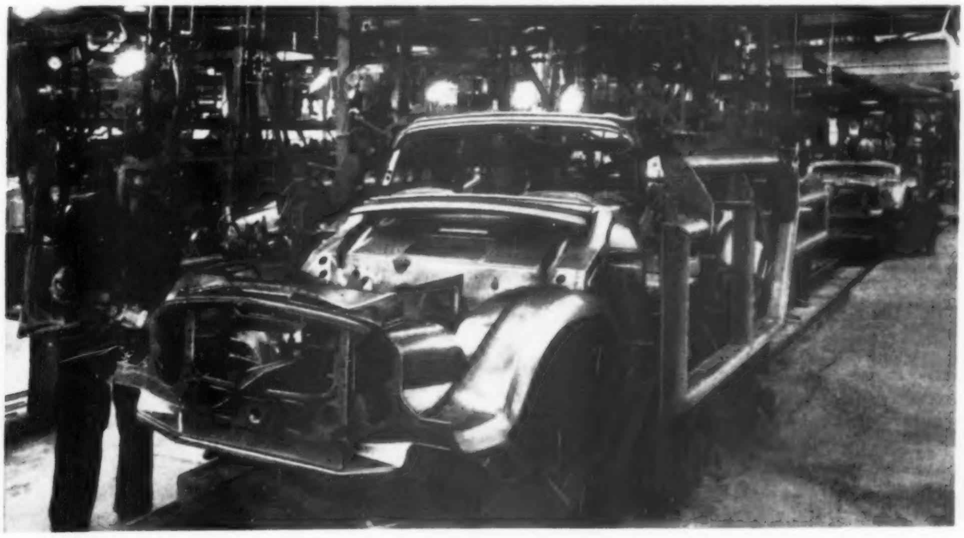
On the left is a radial drill converted by the author, approximately 1920-21, into a four-spindle machine for milling combustion chambers, and on the right is the cylinder block boring line now used for the production of units for the current Hillman Minx engine

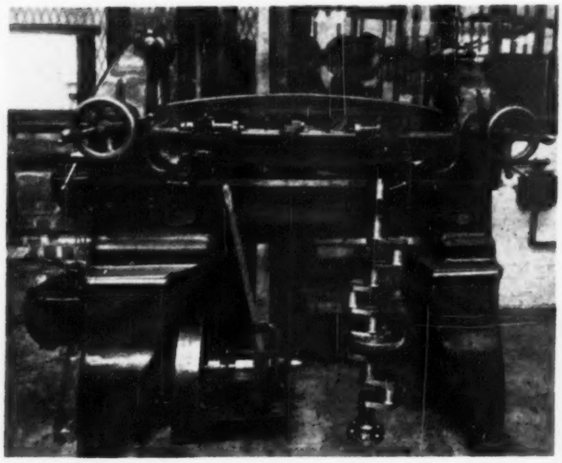
produced, at Vauxhall Motors, the prototype of the Ricardo, six-cylinder, single sleeve valve engine, and the Wilson epicyclic gearbox. The production problems associated with both these ideas were to catch up with me again in 1929 in the Daimler Company. It was an interesting exercise of ingenuity to produce these unusual designs by the adaptation of standard machines with special devices.

During the period between the wars special purpose machine tools were developed, and the principle of flow production was introduced. Up to this time, the car designers were pioneers and had everything their own way, but now they found that their production colleagues were becoming an important factor and had to be drawn into the scheme of things at an earlier stage. As machine tools and special tools were introduced to meet the increasing demand for production at competitive prices, so the designer had to meet these changing conditions, and had to consider not only the customer's eye but also his pocket.

In 1926 I first visited America and, although full of the ambition and eagerness of youth to enter into the spirit of what was then called mass production, I was shocked and frightened by what I saw. Not only the vast machine shops with permanently set up special machine tools but also the assembly tracks caused me to shudder! One set-up at

Compare the assembly of this modern Humber car body, produced by British Light Steel Pressings Ltd., with that on the left





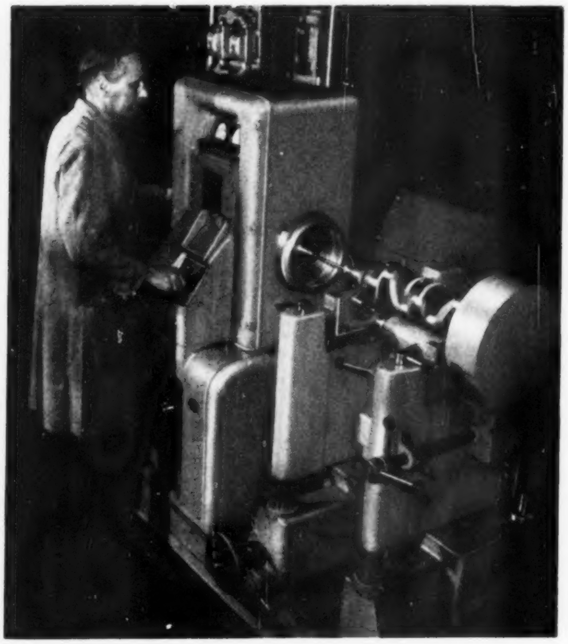
This relatively simple dynamic balancing machine for crankshafts was designed by the author soon after World War I, in the year 1922

Tarry Town, New York, was assembling cars and mounting bodies at a rate of one every 1½ minutes, on each of two fast-moving mechanical tracks.

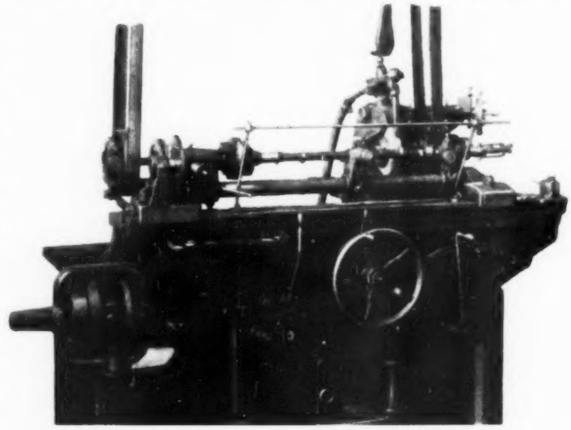
I had gone there at the request of the Vauxhall Motors management—then taken over by General Motors—to investigate mass production of 200 cars a week (one every 14 minutes dayshift). It was difficult to convince our American contemporaries that we were thinking in terms of 200 per week, not per day: they seemed to think that this latter low rate of production was not worth while. One major development there was the large press shops for the production of body panels, and it was obvious to me that the extensive welding operations necessary would eventually entail the mechanization of body assembly. In every case I found the American engineers to be not only generous with their ideas and opinions, but also keen to discuss any point whereby an improvement might be made. It was during this visit to America that I first began to appreciate the importance of team work, which was much in evidence in their project work.

In England and Germany the development of press shops for the production of panels, mudguards and other components, as separate pressings to be applied to wooden structures and bolted to chassis frames, was the first stage towards the all-steel all-welded body. It heralded the major change from the old coachbuilding craft, 200 or 300 years old, and from the panel beater, with his unique skill, to the press tool and die maker who were the skilled machinist and fitter in a new guise. The woodworkers no longer made the structural part of the body but still provided certain timber components, chiefly for interior decoration. During the years before World War II, the flow system for machining and assembly had also developed. Mechanical units such as engines, gearboxes and axles were no longer assembled on a fixed stand by one man or one team but, instead, on moving tracks, with each operator carrying out a specific operation and many working together in a gang.

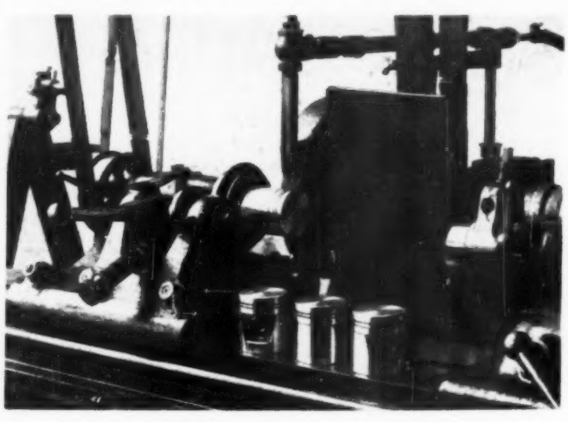
At the Daimler Company's factory, where I was Works Manager, we put the assembling of chassis on a progressive line basis in 1929. The line was not mechanized, but the chassis frame was placed upside down, and first the front and rear axles, with their springs, were assembled, and then the wheels were mounted. Next the whole unit was turned over and pushed from station to station for other units, such as engine and gearbox, dash facia and mudguards, to be assembled. Up to that period, cars were laid down—like the laying down of the keel of a ship—on one spot and,



It is of interest to compare this modern machine for the balancing of crankshafts for the Hillman Minx engine with that on the left



Above, the author's adaptation of a universal grinding machine for cams on the early Vauxhall engines; below, the same machine with an attachment fitted for grinding the elliptical form on piston skirts



when completed, they were delivered to the running shed, an operation analogous to the launching of the hull of a vessel to be subsequently fitted out and finished.

During the period between the wars, this flow system, in both the machine shop and in the unit and car assembly shops, became the standard practice. Operators became more specialized in their knowledge and application, and with the increased accuracy of components turned out by the machine shop, the product became more consistent and more reliable as the volume of production increased.

In 1921 the Institution of Production Engineers was formed, most of its members then being from the machine tool and motor car industries. The journal *Engineering Production*, for which the then editor of *Automobile Engineer* was also responsible, played a leading part in sponsoring this Institution. It was realized, following World War I, that there was a great need to develop the special technique and science of production, and consequently there was an increase in the rate of acquisition and spread of knowledge throughout the country, particularly in the motor car field.

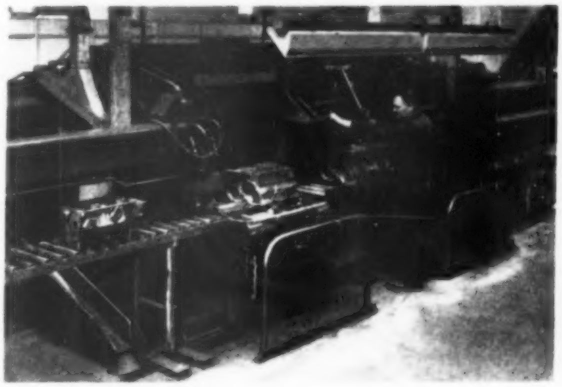
Unitary construction of bodies in large scale planned volume was adopted in Great Britain just before World War II. The industry was once more developing advanced production techniques, including new methods of painting, and better paint materials were becoming available. Owing to increasing volume of manufacture and cost saving, body production was now placed in the hands of engineers, as distinct from coachbuilders. By this time the plant and equipment for assembly and painting had been developed to such an extent that its complexity and significance in the production process was as great as that of the presses or machine tools. Now the body designer, too, found it was necessary to take his production colleagues into consultation at an early stage. Details concerning not only the shape and joint lines of pressings but also the methods of finish and painting had to be considered at the initial specification stage.

During World War II, the motor industry once more played its part in the production to meet military requirements. Thanks to the adaptability of those employed in the industry, the change from cars to aircraft, guns and an ever increasing variety of highly specialized and accurate devices, was quickly accomplished. This time many of the production methods of the car industry were adapted to the manufacture of aircraft and aero engines, and this made it possible to produce intricate components and assemblies in vast quantities with semi-skilled and female operatives. It was now the practice to have standards rooms, and great advances were made in respect of methods of control to very fine limits, as well as vast increases in productive quantity. Then for the first few years following World War II, the car industry, despite shortage of certain basic materials—which affected certain aspects of quality, such as plating and painting—was quickly back into large scale production of vehicles.

Whereas in 1920 there were approximately 80 car manufacturing firms, now five groups produce approximately 95 per cent of the total output of vehicles. But the car industry is not just the Big Five: it includes at least 4,000 firms of specialist suppliers who, by adopting the latest production techniques and equipment, have also kept pace with the need for increased volume and improved quality. The hackneyed story of having to buy-out a certain part because it is too difficult or costly to make-in represents a tribute to the production ability of the industry's specialist suppliers.

The production story of wheels is as revolutionary as any. An accompanying illustration is a reproduction from a photograph taken in a factory in which wooden wheels for cars were made. Adjacent to it is another illustration of a modern transfer press line for making wheel centres, which are the modern equivalent of spokes, at the rate of many thousands a day.

One of the many outstanding changes in car production is in the trimming, which is developing to a stage where seat covers, door trim pads and head-cloths are assembled by electrical and mechanical machines. New materials are constantly being introduced and applied in new ways and with ever advancing techniques. In the production of



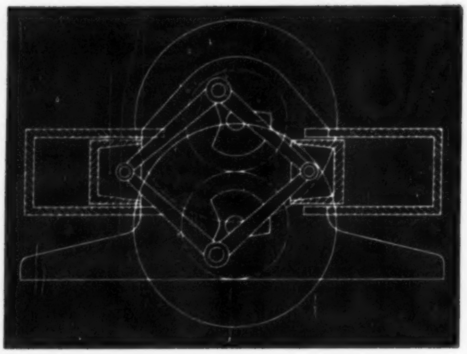
Modern machine for broaching the main joint faces on cylinder blocks

mechanical components, the latest trend is towards the better utilization of material. This objective is being attained by the use of permanent mould techniques, upset heading, impact extrusion, die casting of light alloys at high pressure, sintering and cold and hot coining. All these processes will gradually replace those performed by the wasteful, first-operation, swarf-creating machine tools.

All these new techniques, which are essential to modern production methods, involve high equipment costs and up to two years to tool fully and equip for a new project. No longer can the coachbuilder be asked to put immediately an extra ½ in into a door, as from tomorrow. Today, an extra ½ in means many thousands of pounds in tool charges and many months to make the tool changes; there may even be an interruption of production. The production manager can no longer send home hundreds of men for a few weeks, while he brings in a new model or new plant. Now, the planner's skill is exercised in the overlapping of the production of a new model with that of the previous one, with a resultant continuity in respect of employment and production.

A crankshaft, a camshaft or a gear look much the same as they did fifty years ago, but how much more accurate and more beautifully finished they now are! This is the result of the new production techniques in which, more than ever, skilled craftsmen are employed in the making of the new plant, machinery and measuring instruments. After all these years of development by the designer, and particularly by the production engineer, I am still out of breath trying to keep pace with the new developments in production methods.

However, there certainly need be no fear for the future: the young qualified production engineers now emerging will be as good or even better than their fathers. Finally, it is appropriate to pay a tribute to those fathers—mechanics, production engineers and works managers—contemporaries of mine, who over the past fifty years have taken the major steps in production development, leading to greater accuracy and greater volume. These men have helped to develop the motor industry throughout the world to the attainment of its present major contribution towards overall progress.



In the early 1900s, F. W. Lanchester designed this engine, which provided perfect primary and secondary balance by means of two contra-rotating crankshafts geared together

STORY OF THE

The Genesis and Evolution of the Spark Ignition

SIR HARRY R. RICARDO, LL.D., F.R.S.*

ALTHOUGH I have been invited to write my recollections of the changing phases of design and development of the road vehicle engine during the last fifty years, I should like to claim the privilege of an old man, to go back to still earlier days; for it was during the first decade of the century that the mechanically propelled vehicle emerged from the so-called horseless carriage of the last century to the practical vehicle of 1910, differing but little in its essential features from the automobile of to-day. At the opening of the century the horse still reigned supreme and, while the horseless carriage was a fascinating toy for the mechanically minded, it could scarcely be regarded as reliable or practicable means of transport.

The first decade of the century was to me the most exciting and interesting one, in that it was a period of intensive experiment when almost every conceivable type and shape of prime mover was competing for survival on the road. It saw the rise, the zenith and the twilight of my old love, the steam car. It saw most of the major changes in the design and development of the petrol engine from the single cylinder unit, with an automatic inlet valve and a surface or wick carburettor, to the four or six cylinder engine of 1910. In that period also was witnessed the advent of the sleeve valve engine and, furthermore, the evolution of many interesting and original designs aimed at eliminating vibration, which in many of the petrol engined vehicles of that date was quite intolerable.

For the first five years of the decade, there was a period of invention. It was a golden age for the great pioneers such as Lanchester, Royce and Rowledge, unfettered as they were by fashion or convention—this was also an age when witch-doctrine still played its part. It was, too, the heyday of the steam car, whose complete freedom from vibration and almost complete silence set a high standard for the petrol engine to emulate.

The next five years was rather a period of elimination, when most of the earlier types were weeded out until, by 1910, the four and six cylinder in-line engines had won the day. During this period, the horseless carriage had developed into the automobile, becoming a thoroughly reliable vehicle. In fact, the picture had changed completely: the horse had now become the plaything and serious road transport was handled by the automobile, which had begun to compete even with the railways.

Most original and successful of all the freak designs before 1910 was, I think, the famous Lanchester engine with two opposing horizontal cylinders, each piston of which was coupled to two crankshafts, one above and one below the centre line of the cylinders. Since the crankshafts ran in opposite directions of rotation, not only was a perfect dynamic balance, both primary and secondary, achieved but also, because each crankshaft carried at one end a heavy cast iron flywheel, torque reaction, too, was almost completely balanced out. At a time when most other petrol engines gave rise to excessive vibration and noise, this completely vibrationless engine stood out in extraordinary contrast.

Apart from the unique design of the engine, the car itself bristled with new and original features, many of which have remained standard practice to this day. Looking back, I think it is fair to say that the early Lanchester car marked the point of departure from the horseless carriage of the last century to the automobile of to-day, that is to say to the vehicle designed, *ab initio*, for mechanical propulsion.

Lanchester's vibrationless engine spurred other car manufacturers to attain the same ends by other means. Rolls-Royce, Napier and others sought to do so by the development of the six-cylinder in-line engine — a bold departure in view of the popular belief at that time that the more cylinders the greater was the likelihood of engine failure. Gobron-Brillié in France and Arrol-Johnston in Scotland, with the same ends in view, developed engines with two pistons in each cylinder, reciprocating in directions opposite to each other, but both coupled to the same crankshaft, the former by means of long return connecting-rods from the outer pistons as in the modern Doxford marine engine, the latter through the medium of rocking beams to a single crankshaft immediately below the cylinders, as in the modern Commer diesel engine. Both were very successful in their day and won many laurels in road racing and other competitions. The first Tourist Trophy race in the Isle of Man was won by an Arrol-Johnston car with a two cylinder engine of this type.

Dread of the multi-cylinder engine as a means of reducing vibration and torque reaction derived, for the most part, from the notorious unreliability of the automatic inlet valve and, to a lesser extent, from that of electric ignition systems. The advent of the magneto went a long way to restore confidence in the latter, but the automatic inlet valve died hard. On the one hand it was argued that the cost of an additional set of cams, tappets and other components in the valve train would be prohibitive, and on the other, that the automatic valve opened when the time was ripe whereas, when mechanically operated, it had no such discrimination. Both arguments had some validity, at all events at that time, when machining costs with conventional tooling were high, and when lack of turbulence in the combustion chamber could result in a lingering flame igniting the incoming charge and so firing back into the carburettor. By 1910,

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ENGINE

and Diesel Power Units for Motor Vehicles

however, both the automatic inlet valve and the wick or surface carburettor had disappeared from the scene. The multi-cylinder engine had won the day.

From a mechanical point of view probably the most outstanding development of that period was that of the famous Model T Ford engine and the new technique of manufacture which went with it. This marked a new epoch in both design and manufacture, the techniques of which have become universal practice to-day. In this four-cylinder engine the upper half of the crankcase and the cylinder block were a single iron casting, while the one-piece cylinder head, covering all four cylinders, was detachable and the joint was made both gas and water tight by means of a thin copper and asbestos gasket.

Such, in brief, is my recollection of the march of events and the state of the art by 1910. Subsequent developments, I think, are best dealt with under separate headings.

Combustion

Prior to 1910 the automobile engine designers had, for the most part, paid but scant attention to the factors governing the process of combustion or to thermodynamic principles generally. Their engines were often masterpieces of mechanical design, but mechanical expediency was the dominating factor. It was generally accepted that as high a ratio of compression as possible should be used, subject to the limit imposed by engine knock; and it was the almost universal belief that knock was due to premature ignition. To suggest, as Hopkinson had hinted several years before, that knock might be a phenomenon distinct from and almost unrelated to pre-ignition, was then widely regarded almost as heresy.

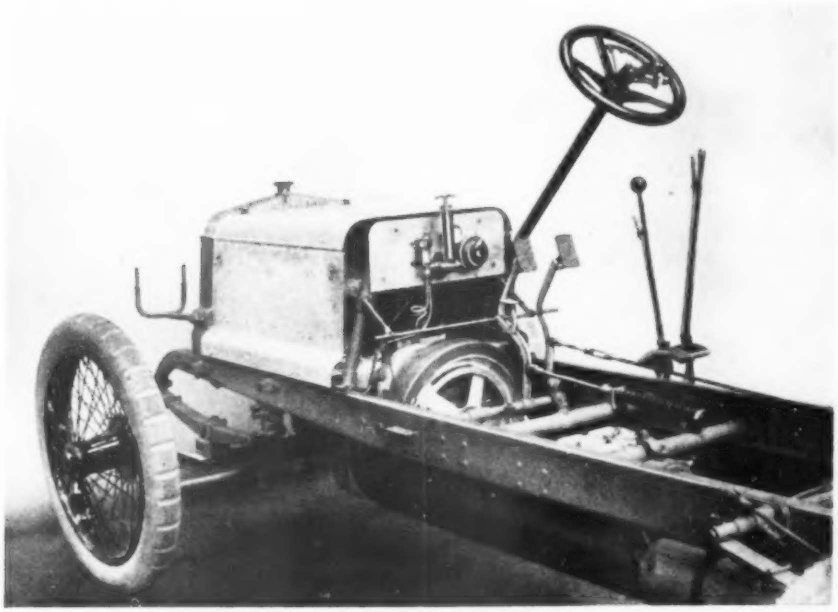
It was realized, of course, that the heat losses to the cylinder walls should be kept as low as possible by keeping the surface : volume ratio to a minimum, but a close study of the engine designs of 1910 will reveal that often only lip-service was paid to this principle. Although both Hopkinson and Dugald Clark had long since demonstrated the vital part played by turbulence in speeding up and controlling the process of combustion, there is no evidence of the importance of this factor having been taken into account.

The result of this lack of appreciation of the several factors influencing the process and efficiency of combustion was that some engines proved to be very woolly and sluggish while others, for no very obvious reason, turned out to be very lively. It seemed to be just a matter of luck.

Early in the First World War it became evident that the I.C. engine would play a vital part both in aircraft and in other military applications, with the result that ample funds became available for research, many fresh minds were brought to bear on the problem and many of the early mysteries disposed of. Understanding of the mechanism of the knock, which set an upper limit to the compression ratio that could usefully be employed, was slow in coming. Slower still was the realization that the tendency to detonate was primarily a function of the chemical composition of the fuel but that, to a limited extent, it was susceptible to treatment by keeping the length of flame travel as short as possible and by ensuring that the end-gas remote from the sparking plug had every possible opportunity for getting rid of the heat thrust into it.

As to the influence of turbulence to speed up the combustion process, this was a factor that was generally ignored. Without turbulence it would be impossible to run spark-

A typical Daimler car chassis of 1910-11, fitted with a 25 h.p. sleeve valve engine. The sight feed for the lubrication system can be seen on the panel attached to the dash structure; next to it is the hand operated pump for priming the fuel line. Another interesting feature is the use of an external helical spring for the clutch return



ignited engines at high speed: that, in fact, engines were able to run fast was due to the random turbulence set up by the velocity of the gas entering through the inlet valve. In the case of overhead valve engines with high-lift valves opening directly into the cylinder, the turbulence thus created was adequate but, where the inlet valve was pocketed or where the velocity of flow through the valve was low, the engine stood in need of some increase in turbulence. However, by 1920 the basic principles covering combustion chamber design had become well known and were being applied by engine designers.

Fuels

Prior to the First World War, petrol consisted of any volatile fractions distilled from crude petroleum, whose specific gravity did not exceed a certain arbitrary figure. The early use of the wick or surface carburettor had put a very high premium on volatility—in general, the volatility of petroleum products is more or less inversely proportional to their specific gravity. Though the surface carburettor had long since faded out, the specification for petrol, on the basis of specific gravity, had remained unchanged.

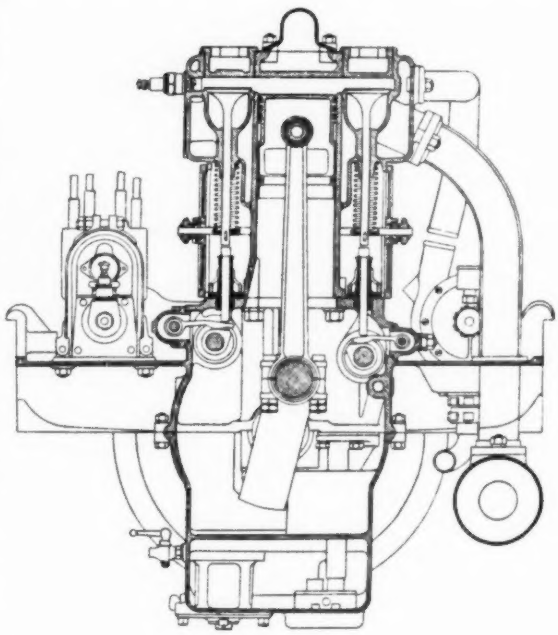
Although by 1915 it had become generally accepted that the incidence of detonation was the over-riding factor controlling the performance of the spark ignition engines, surprising though it may seem, no serious efforts had been made to investigate the chemical and physical properties of fuels in relation to their tendency to detonate. Such an investigation carried out during the latter phases of the First World War revealed that, of the main constituents of petrol, the paraffins were the worst offenders, the aromatics the best behaved and the naphthenes somewhere midway between the two. Of these three components, the paraffins have the lowest specific gravity and the aromatics the highest. The relative proportions of these main components varied widely as between one oilfield and another, and it came as a shock to learn in 1917 that thousands of tons of the best highly aromatic petrols were being burned to waste simply because they did not comply with an out of date specification based on specific gravity.

It is customary nowadays to classify fuels in terms of octane number: the higher the octane number the less prone are they to detonate and, therefore, the higher the compression that can usefully be employed. Up till about 1921, the octane numbers of the petrols supplied for road vehicles ranged between 40 and 50, and compression ratios were limited to between 3·5 and 4·5:1, depending on the size and form of the combustion chamber. From about 1921 onwards the octane number of petrol has increased progressively; at first by blending with other aromatics such as benzol and/or by the introduction of small quantities of tetra-ethyl lead, and later also by breaking down and re-forming the molecules during the refining process. To-day, with octane numbers between 90 and 100 it is possible to employ compression ratios of the order of 8:1, or even higher, and it is to the great improvement in the quality of the fuel, more than to any other single factor, that the increased performance of the petrol engine of to-day is due.

Mechanical design

By 1910, the design of petrol engines for road vehicles had already reached a very high level. The multi-cylinder in-line engine, with either four or six cylinders, had become almost standard practice both in this country and abroad. Outstanding examples, from that period, are the famous Rolls-Royce six cylinder Silver Ghost, the six cylinder Napier and the four cylinder Vauxhall, Sunbeam and Talbot engines. Considering the very low compression ratios imposed by the fuels of the day, the performances of these power units was a really remarkable achievement.

The bogey of vibration had been almost completely laid by the use of six cylinders and partially at least by the use of four. In the latter case, however, the unbalanced secondary forces, in conjunction with the use of heavy cast iron pistons, were still very troublesome, while in the six cylinder engines, crankshaft torsional oscillation gave rise, at that time, not so much to broken crankshafts but rather to noisy timing gears, and very unpleasant vibration at certain critical speeds. Somewhere about 1912, Lanchester patented his well known torsional vibration damper consisting of a small loose flywheel, fitted to the forward end of the crankshaft and coupled to it through the medium of a number of thin discs immersed in oil. This damper, relying on viscous friction, proved most effective, but difficulty was sometimes experienced owing to loss by leakage and to the wide variations in the viscosity of the oil with temperature.



This Sunbeam four cylinder engine of 1911 had an integral cylinder block and head casting. A T-head layout was employed, and access to the valves was afforded by removing the plugs screwed into the head

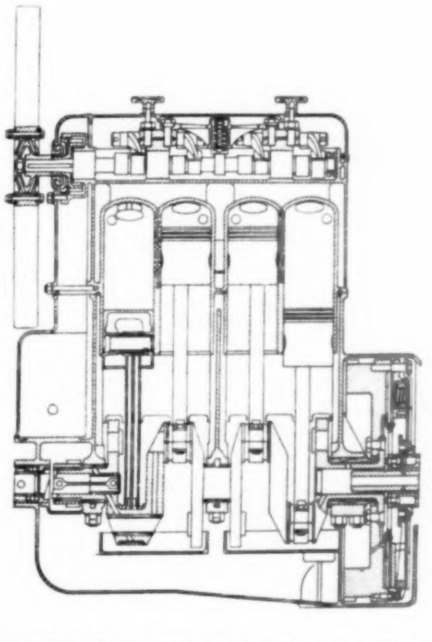
Later, the coupling of the flywheel was effected by synthetic rubber, bonded to the metal components; more recently still, the employment of viscous friction has come into favour again, but silicones, whose viscosity varies little with temperature, are used and leakage of the casing has been overcome by welding after filling.

Simultaneously with Lanchester's invention, Royce overcame the difficulty of torsional oscillation by using a non-rigid attachment for his engine flywheel and, as a further refinement, by incorporating a spring-drive in his timing gears.

High-frequency vibration, owing to the unbalanced secondary forces in four cylinder engines, became increasingly troublesome as engine speeds increased. At one time it seemed as if the more expensive and longer six cylinder engine would displace the four cylinder unit altogether, even in the case of quite small engines. The introduction, however, and general use of light, aluminium pistons went a long way towards reducing the effect of out-of-balance secondaries, and so the four cylinder unit remained popular.

Several ingenious devices had been patented for balancing out the secondaries, the best known of which was Lanchester's device consisting of two oppositely rotating balance weights running at twice engine speed, mounted just under the centre bearing and driven by spiral gears from the middle of the crankshaft. This was used for a time by Vauxhall and, I think, several other makers but, though very effective, it was expensive to make and apt to be noisy. Yet another method proposed, but never applied was to utilize the whole mass of the engine as a balancer by oscillating it up and down at twice engine speed, a vertical displacement of a few thousandths of an inch being all that was needed.

The introduction of synthetic rubber, with its excellent damping and oil resisting properties, provided a simple means of circumventing the vibration problem. Looking back, I think that the introduction of resilient, rubber mountings was perhaps the most important development of the last 30 years. Without it, the very high-speed four cylinder engines of to-day, with their short connecting-rods and unbalanced secondaries, would have been impossible.



Trough lubrication of the crankshaft bearings was employed before the general adoption of pressure feed. The position of the troughs is clearly shown in this illustration of a Fergus engine built about 1919

I have stressed the question of vibration, because I think it was the most important problem in the early days of the petrol engine. The lack of dynamic balance in the single and two cylinder engines, with the heavy cast iron pistons of that date, led to intolerable vibration, especially, of course, in the lower gears; and I can well remember that when driving a certain car, I used, when climbing a hill in bottom gear, to get out and walk alongside, not to relieve the engine of my weight but simply because the vibration became unbearable!

Noise

Engines of the 1910-1920 era were relatively noisy, owing partly to lack of any sound insulation and partly to their crude valve mechanisms and cam designs. In those days it was unusual to enclose or lubricate components such as the valve stems and push rods. In consequence, wear was rapid and the tappet clearance had constantly to be taken up.

Just as in the first decade of the century, the steam car set a high standard of silence, so in the second decade did the advent of the sleeve valve. To compete with this, the designers of poppet valve engines were forced to look carefully into the geometry of their cam designs and to enclose and lubricate their valve mechanisms; and by about 1930, the poppet valve engine had, in general, reached almost as high a standard of silence as the sleeve valve unit, and the latter faded out of the picture so far as road service was concerned.

Valve position

During the period 1910 to the early 1920's, the side-by-side valve arrangement, with integral cylinder heads and detachable plugs for insertion of the valves, was the arrangement most in favour on the score of ease of production and accessibility—at a time, of course, when bonnets opened at the side—and also on the score of silence owing to the small amount of lost motion between the cam and the valve stem. This form of engine was very prone to detonate and gave a rather woolly and poor performance, because of the length of flame travel and lack of turbulence. The use of integral cylinder heads and detachable valve caps compelled a rather wide spacing of the valves and, therefore, limited their size and so curtailed the breathing capacity of the engine.

Next in favour came, for a period at least, the T-head arrangement, with side valves, the inlet and exhaust valves being on opposite sides of the cylinder and operated by two camshafts. This was claimed to have all the advantages of the side-by-side valve arrangement, in respect of silence, accessibility, etc., plus the added advantage of ample breathing capacity in the same overall length of engine. Unfortunately, however, the form of combustion chamber was so unfavourable, owing to the great length of flame travel and lack of turbulence, that the advantage of increased breathing capacity was more than offset by the slow rate of combustion and the need to restrict the compression ratio to a very low value because of proneness to detonate.

The overhead valve engine with vertical valves opening directly into the cylinder gave a markedly improved performance compared with either the side-by-side valve or T-head engine. This was attributed to better breathing capacity, but was, in fact, due to the compact form of combustion chamber and the relatively high degree of turbulence. Such engines could operate with at least half a ratio higher compression and required far less spark advance than the contemporary side valve type. The objections to this arrangement then were that the valve gear involving long push rods and many joints was apt to be very noisy, while the fear of a valve falling into the cylinder was in those days a very real one.

The overhead valve arrangement with one or two overhead camshafts and a hemispherical or pent-roof combustion chamber, favoured by aero-engine designers, was and still is the favourite layout for racing engines, and remains the almost ideal form, in that it provides ample breathing capacity and turbulence and the shortest possible flame travel; apart from in aero-engines and racing cars it achieved great success as a high performance car engine in the famous 3 litre Bentley and Sunbeam engines of the early 1920's and more recently in the Jaguar units. By 1920, the overhead valve engine operated by push rods, by virtue of its better performance, was rapidly displacing the side valve; however, by supplementing the normal induction turbulence with some additional turbulence set up during the compression stroke, and by reducing the effective length of flame travel in the side valve engine, a performance equal to that of the overhead valve engine with vertical valves could be achieved,

and the side valve returned again into favour, remaining so until the progressive improvement in fuels permitted the use of compression ratios of 6:1 and over. Beyond this, the small clearance volume needed rendered it geometrically impossible to provide adequate breathing capacity with side-by-side valves outside the periphery of the cylinder.

Stroke : bore ratio

During the first decade of this century, every extreme of stroke: bore ratio ranging from 2½:1 down to 0·6:1 was to be found. By 1910 the ratio had settled down to between 1:1 and 2:1 though some extremes remained, for example, the Lanchester four and six cylinder engines of 4 in bore and 3 in stroke. For high-performance sports cars, the long-stroke engines, such as the Hispano-Suiza, 80 × 180 mm, the Vauxhall 30/98, of 95 mm × 140 mm, and the Bentleys, were to rule the day for a long time to come.

In the early days it was the almost universal practice to employ an aluminium crankcase, with a separate cast iron cylinder block. The relatively long stroke provided a good deep crankcase, reinforced by the cast iron cylinder block which functioned as a rigid girder to resist the bending moment of the opposing couples in both four and six cylinder engines.

In the late 1920's or early 1930's the American practice, initiated by Ford, of casting the cylinder block and crankcase integrally, together with the technique of mass production, came into vogue in Europe. With this form of construction, on the score both of weight reduction and ease of handling and machining, it is desirable to keep the overall height of the castings as small as possible, by the employment of a short stroke and the shortest practicable connecting-rods. This means, in the case of four cylinder engines, very large unbalanced secondary forces which, but for the resilient rubber mounting, would render such engines unacceptable. The chief result of the reduction in stroke has been a corresponding increase in rotational speed in order to achieve the same piston speed—for the output of any I.C. engine is a function of mean pressure and piston speed. Over the past 40 years, although piston speeds have increased hardly at all, rotational speeds have almost doubled. This has resulted in greatly increased friction losses, owing to the greater inertia and centrifugal loadings and the higher rubbing speeds; it has also brought into prominence problems such as valve bounce and oil control.

Output

While the piston speed of modern petrol engines has increased but little during the last 40 years, mean effective pressures have risen considerably as a direct result of the very much higher compression ratios rendered possible by improvements in the fuel. In 1910, with compression ratios of about 4:1, we used to consider a maximum b.m.e.p. of 85-90 lb/in^2 a very creditable performance, and power curves usually peaked at a piston speed of about 1,500 ft/min.

By 1920, thanks to improved combustion chamber design, but not yet to improved fuels, compression ratios had in general increased to 5:1, and a well proportioned engine designed at about that time was expected to have a b.m.e.p. of at least 110 lb/in^2 — the best examples gave over 120 lb/in^2, with a peak cylinder pressure of 500 lb/in^2. By the same date, piston speeds had risen from 1,500 to well over 2,500 ft/min. This large advance in the performance of engines designed and developed immediately after the war was due to the intensive research and development work on aero-engines during the war years.

Improvement in the quality of fuel did not become general until some years later, and the engines of the early 1920's had still to be capable of operating on fuels of 45 octane rating. To-day, with compression ratios of the order of 8:1, we expect a b.m.e.p. of 140-150 lb/in^2, but with a peak cylinder pressure of 800-900 lb/in^2. I find it difficult to see that any worthwhile advantage is to be gained by employing ratios substantially higher than 8:1 in petrol engines.

Lubrication

In the very early days of the petrol engine, the lubrication of components such as the bearings and pistons was either effected by individual supply from an array of sight feed lubricators on the dashboard, or purely haphazardly by the injection, from time to time, of a pumpful of oil into the crankcase, and relying on splash to distribute it among the various working parts. By 1910, however, it had become the general practice either to rely on troughs, fed by an oil-circulating pump, into which the connecting-rod big ends dipped, or, following contemporary high-speed steam engine practice, to force the oil under pressure between the actual bearing surfaces. So long as the mean loading and rubbing speeds were not too high, oil was needed only for lubrication and it was sufficient merely to wet the bearing surfaces but, with the increased friction due to higher loads and rubbing speeds, the oil was called upon to serve also as a cooling agent: hence it became necessary to provide a rapid circulation through the crankshaft and big end bearings.

There was much to be said for the old systems of troughs and splash, in that wear was markedly less because little or no grit was circulated through the bearing surfaces to cause abrasive wear; also, only a very rudimentary oil filter was required. However, during the last thirty years, high pressure oil circulation combined with very meticulous filtration has become standard practice and, to-day, we have to circulate five or six times as much oil as we used to do in the 1920's. This has added to the problem of controlling the passage of oil past the pistons, which are still lubricated by splash.

In the early 1920's complaints of rapid cylinder bore wear rose to a crescendo. Since this phenomenon coincided with the introduction of aluminium pistons, it was not, perhaps, surprising that they were thought to be the culprits, and several firms reverted for a short time to cast iron or steel pistons, but without any diminution of cylinder bore wear. That the trouble had not become prominent in earlier years was, however, probably due to the lower utilization factor before the First World War.

About the middle 1920's, research had revealed that by far the largest proportion of the wear was due to chemical corrosion caused by the condensation on the cylinder walls of the acid products of combustion, such as sulphur trioxide and formic acid, and that the remedy lay in bringing the cylinder bore temperature as rapidly as possible up above the dew point of these highly corrosive products. Several years, however, elapsed before thermostatic control of the cooling system became widely adopted. In fairly recent years a further refinement, namely the use of chromium plated piston-rings, has still further reduced the rate of cylinder wear. Oil additives, too, are now used to good effect to reduce corrosive wear.

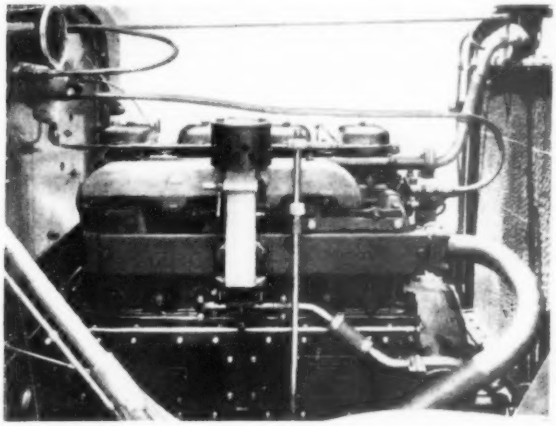
In the early days of the petrol engine, it was the usual practice to employ white-metal bearings in the form of a fairly thick lining cast into a gunmetal shell. So long as the peak loading did not exceed about one ton per square inch of projected area, and the lining was well cooled by oil circulation, these bearings behaved very well, but they were superseded by the modern strip bearings with a very thin white-metal lining, which would stand a higher loading. However, in the early 1930's, with the advent of the diesel engine, and its much higher cylinder pressures, a lining with better physical properties had to be found. The problem was solved by the employment of a copper-lead lining overlaid with a very thin flash of lead, tin or indium. Such

bearings can withstand a specific loading more than twice that of white-metal: hence the bearing width could be and has been reduced considerably and some reduction thereby achieved in the overall length of the engine.

The diesel engine

While there seems comparatively little to record about the progress of the petrol engine during the last 30 years, that same period has seen the arrival and the triumph of the diesel engine which, in Europe, has now completely displaced the petrol engine in the heavy commercial vehicle field and is even beginning to trespass into the private car's domain.

Prior to 1910, only diesel engines with large power outputs, for stationary or marine use, were built; they were regarded as a highly efficient, but relatively heavy and costly form of prime mover. The injection of fuel into the cylinder was effected by means of a blast of air under high pressure. This air blast served the purpose of pulverizing the liquid fuel, of distributing it effectively throughout the air in the combustion chamber, and of setting up the turbulence necessary for rapid combustion. Unfortunately, the equipment needed to compress the air, at about 900 lb/in^2, was a very costly and fragile piece of apparatus. So long as the functioning of the engine depended on an air blast, its application to road transport was out of the question. Much ingenuity had been expended in the endeavour to dispense with the blast, but with only limited success.



Modified Gardner marine engines were used in the first successful British applications of diesel power units to commercial vehicles. In this view is seen a typical installation of a Gardner 4L2 engine

To Hesselmann, I think, belongs the credit for having initiated a new line of thought. He argued that if the fuel cannot be sent to find the air needed for its combustion, why not set the air to find the fuel? At that time, about 1911, Hesselmann was building large submarine engines for the Swedish Navy. In these engines he injected the fuel as a number of relatively coarse streams radiating from a central pepper-pot type of injector. In addition, by masking part of the circumference of the inlet valve, he contrived to set the air into a rotational swirl in such a manner that it flowed past the jets of fuel more or less at right angles, thus bringing fresh air to each jet and, at the same time, washing away the products of combustion. By adjusting both the rate of air swirl and the number and spacing of the fuel jets he succeeded in equalling the performance of the air blast engine.

Some twelve years later he developed a low-pressure spark ignition engine with fuel injection, in which he also employed a rotational air swirl but for a different purpose. Today, most automobile diesel engines follow the principle adopted by Hesselmann, but whether the requisite air swirl be set up by directing the intake air into an open chamber or by compression through a tangential passage into a separate swirl chamber is a matter of choice, depending on the circumstances.

At an even earlier date, Brons, a Dutch engineer, achieved a fair measure of success by fitting within the main combustion chamber a small capsule or pre-combustion chamber, as he called it, communicating with the main chamber through a number of small holes. Into this chamber he metered, before the commencement of compression, a small charge of liquid fuel which lay there until the compression temperature rose high enough to initiate combustion within the capsule. The sudden rise of pressure within the capsule sent its contents, liquid fuel and combustion products, flying out into the main combustion chamber thus imitating the function of air blast injection but, with this significant difference, that he had no control of the actual time of ignition, which, of course, varied with the temperature of the pre-combustion chamber, and this, in turn, varied with the load or speed. Hence, in practice, the engine could be run only at a nearly constant speed and load; nevertheless, it achieved considerable popularity as a marine engine for applications such as canal barges and fishing boats.

In the early 1920's the Daimler-Benz Co. in Germany developed a modified version of the Brons engine, in which the fuel was delivered to the pre-combustion chamber, towards the very end of the compression stroke, by means of a timed injection pump. With this arrangement the time of ignition could be controlled and the bugbear of premature ignition eliminated; thus from the early Brons engine there grew, by a process of progressive detail refinement, the highly successful Mercedes-Benz pre-combustion chamber type diesel engine of the present day.

During the First World War and the years immediately following it, the consumption of petrol rose by leaps and bounds. This left the oil companies with a glut of the heavier distillates, such as gas-oil, which could not be carburetted: hence there arose a strong urge to develop a light high-speed diesel engine for road transport.

During the middle 1920's, many attempts were made to achieve this end and, as in the early days of the petrol engine, a great many varieties were tried out on the road, especially in Germany. The later 1920's witnessed a process of weeding out until, by the 1930's, virtually only two basic types survived in Europe: they were the pre-combustion chamber type, following Brons, and those depending on air swirl, following Hesselmann—in these, however, the swirl was in some instances during induction and in others during compression.

In this country, our first real success with diesel engines in road vehicles was achieved when the Gardner marine diesel unit was tried out in a number of heavy commercial vehicles in about 1930. This engine, which was of the open chamber direct injection type, with induction air swirl, had given an outstandingly fine performance as a high-speed marine engine, owing to its excellent design and superb workmanship. It came, I think, as a surprise to most of us that an engine designed for marine propulsion and intended, at that time, for a maximum speed of, I think, 1,000 r.p.m. should have acquitted itself so well on the road. The unit proved to be capable of running efficiently and reliably at much higher speeds than those for which it was originally designed, and in all round road service it gave about double the mileage per gallon of equivalent petrol engined vehicles.

In the thirty-odd years that have since elapsed, Gardners have, of course, made many detail modifications and

improvements but they have not departed from the basic mechanical features of the design, namely the use of a relatively small bore and long stroke, of a very deep and massively designed crankcase, and of separate cast iron cylinder blocks. The initial success of the Gardner engine in this country at once spurred most of the manufacturers of heavy vehicles to compete, either with designs of their own or by taking licences from abroad.

Pre-chambers have never found favour in this country, although this type of engine is still very popular in Germany. The choice very rapidly whittled down to that between the open chamber type, with either masked valves or directed ports to produce the necessary organized air swirl, or the swirl chamber type in which a much higher intensity of air swirl is set up during the compression stroke. Both have their advantages and disadvantages, which I think are well-known to most automobile engineers to-day. Broadly speaking, for road transport service, the open chamber type with induction air swirl scores, on balance, when the individual cylinder capacity is upwards of one litre and the swirl chamber when it is below this.

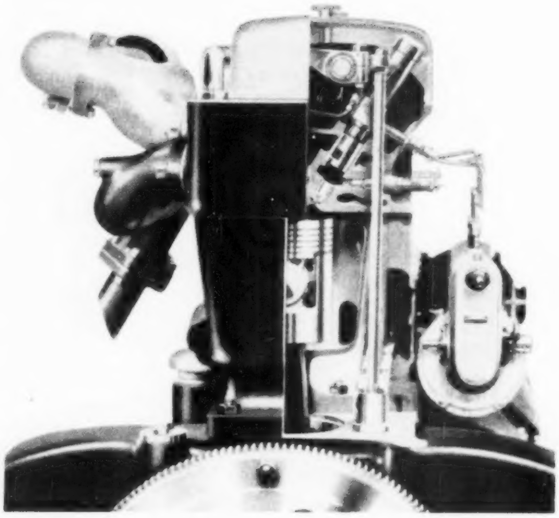
Within what seemed an incredibly short time, almost all the makers of heavy commercial and public service vehicles had changed over from petrol to diesel engines, followed more tardily by the makers of the smaller and more numerous class of commercial vehicle, the farm tractor and the taxi-cab. It is, of course, only very recently that the diesel engine has begun to venture with any success into the last stronghold of the petrol engine, the private car.

From the point of view of specific power output, the diesel engine labours under two disadvantages, as compared with the petrol engine. *Alteris aequis* the power output of any I.C. engine is a function of the weight of oxygen it can consume in unit time. This, in turn, depends upon the amount it can inhale and the proportion of the inhaled oxygen that it can utilize. The petrol engine, using an externally prepared mixture of fuel and air, can utilize virtually the whole of the oxygen entrapped within the cylinder. In the case of the diesel unit, in which the fuel and air are admitted separately, it is not possible to bring the whole of the inhaled air into contact with the fuel, though with a very intense compression-induced air swirl it has been found possible to utilize well over 90 per cent of the inhaled air, and that with a perfectly clear exhaust.

The second disadvantage that the diesel engine suffers is that, owing to the very high compression ratio needed for ignition, the clearance volume in the cylinder is so small, and the need to concentrate that volume in such a manner that the air swirl has full play is so insistent that, in practice, one is virtually forced to use a flat cylinder head with the valves mounted vertically and with their heads contained within the bounds of the cylinder bore. This geometrical arrangement places a severe limitation on the breathing capacity of the engine; moreover, it is a limitation which is all the more severe in the case of engines relying on induction air swirl, owing to the necessity to mask part of the periphery of the inlet valve.

No such limitation applies in the case of the petrol engine with which, because of its relatively much larger clearance volume, either the valve heads can overlap the cylinder bore or inclined valves can be used. Hence the diesel engine suffers in that it can neither inhale so much air nor utilize all the air it has inhaled. On the other hand, thanks to its higher thermal efficiency, it can get more out of the air available for combustion; furthermore, it is not handicapped by any restriction imposed by a carburettor or by the need for pre-heating of the air.

The best small automotive diesel engines that we have tested at Shoreham during the past five years show a maximum b.m.e.p. of about 120 lb/in^2 at the clean exhaust limit,



Daimler-Benz introduced the pre-combustion chamber for diesel engines in the early 1920s. Above is a view of a part-sectioned Mercedes-Benz power unit of 1936, in which the same principle is employed

and their power curve peaks at a piston speed of about 2,500 ft/min. By comparison, we find that the best examples of petrol engines, other than purely racing engines, of the same cylinder capacity and of equally good design, show a maximum b.m.e.p. of about 145 lb/in^2, and their power peaks at about 3,000 ft/min.

All this, of course, applies at peak power output. But at reduced speeds, or loads, the diesel engine scores heavily in that, being able to operate on what is in effect a stratified charge, its thermal efficiency improves as the load is reduced. Hence, from the point of view of fuel economy the diesel unit shows to best advantage in services involving a large proportion of light load or idle running, for example, in city bus and taxi-cab service. In the London bus service, the change from petrol to diesel engines in the early 1930's almost exactly doubled the mileage per gallon of fuel, and the same proportional improvement has recently been experienced in the case of the London taxis.

The diesel engine, by virtue of the fact that it inhales only pure air, is much more amenable to supercharged or to two-cycle operation than is the petrol engine. As to supercharging, the choice lies between the use of the mechanically driven, positive displacement blower, and the exhaust driven turbo-blower, which has the merit of utilizing exhaust energy that otherwise goes to waste. The former has the merit that it can provide a relatively heavy supercharge at the lower end of the speed range, which the turbo-blower cannot achieve, and also no time lag is involved in the build-up of the supercharge.

It would seem that, where the service involves constant slowing and accelerating, as in city bus service or in hilly country with winding roads, the advantage should lie with the mechanically driven type; while on arterial roads where high speeds can be maintained, the turbo-blower will show to best advantage. Both types are currently on trial, and since they serve different conditions, it is probable that both will survive.

As to two-cycle operation, in applications where rotational speed is not limited by circumstance or convention, the four-cycle engine scores by virtue of its higher overall mechanical efficiency at high speeds, when the work done in charging the cylinder with air begins to become the significant factor. In the two-cycle engine this factor is even more important,

because a considerably larger volume of air has to be handled. But there are compensations: for example, in single-piston engines the cylinder head is much less congested and therefore less liable to crack, while in the opposed piston types there is no cylinder head at all. It would seem that the latter is probably the best version for road service. The current, apparently very successful, Commer opposed piston unit is really a two-cycle diesel version of the old Arrol-Johnston petrol engine, which performed so well in the very early days. The layout of this engine has always appealed to me as the most elegant way of coupling opposed pistons to a single crank.

From a mechanical point of view, the problems encountered during the development of small high-speed diesel engines during the last 30 years have been much the same as those of the petrol engine. They have been accentuated, however, by the much higher cylinder pressures and by the greater local intensity of heat flow to the pistons and to some areas of the cylinder heads. Such problems can be solved only by the combination of detailed research and analysis of the experience gained over many years.

While the diesel engine has already swept the board so far as commercial vehicles are concerned, its application to cars has been delayed by two factors: one is the extra cost of such engines, which is largely due to that of the injection equipment, and the other is the rougher and noisier running owing to the high cylinder pressures and to the so-called diesel knock, both of which are most in evidence when the engine is idling. As to the rougher running and greater torque reaction, due to the high cylinder pressures, much has been done and much yet remains to be done by improvements in the mounting of the engine in the vehicle and by improved sound insulation.

On the subject of diesel knock, which is due to the rapid rise of pressure following ignition delay, much research has been done and a good deal of progress has been made. Several ways have been found for eliminating it almost completely: they include the use of pilot injection but, unfortunately, so far, all of them bring other evils in their train, such as increased fuel consumption, dirty exhaust and higher cylinder pressures.

Fuels

Performance of the petrol or spark ignition engine depends first and foremost on the composition of the fuel. The higher the self ignition temperature of the fuel the less is the tendency to detonate, and therefore the higher is the permissible compression ratio or, in the case of aero-engines, the greater is the degree of supercharge that can safely be employed. For example, the increase in octane number of aviation spirit from 77 to 100 made it possible almost to double the output of aero-engines.

Diesel or compression ignition engines tolerate best a fuel with a low self ignition temperature. The lower the self ignition temperature the more gentlemanly becomes the behaviour of the engine in respect of roughness and noise, but little or no gain in power output or fuel consumption can be expected from any juggling with the composition of the fuel.

While the modern petrol engine is becoming ever more dainty in its appetite, the diesel unit is growing yet more omnivorous and can enjoy any petroleum distillate except very high octane petrols. In Europe the scope of the petrol engine has virtually narrowed down to that of the propulsion of cars alone, although this certainly is still a very wide field; the petrol engine has been driven from the air by the gas turbine, and from marine and industrial applications by the diesel engine, which has already also elbowed it out of most of the commercial vehicle field. If all piston engines were to operate on a compression ignition cycle, it would be possible to imagine all browsing together on a common swill-tub containing a jumbled mixture of the whole range of petroleum distillates regardless of the structure or size of their individual molecules.

Fifty Years of Bearing Manufacture

ON THE 7th February, 1910, The Skefko Ball Bearing Co. was formed, to manufacture and market in Great Britain the self-aligning ball bearing invented by Sven Winquist, a Swedish engineer, who became the company's first chairman. After some searching for a suitable factory site, three acres were purchased in Leagrave Road, Luton, then on the rural fringe of the town. When the factory was opened the following year, it housed 150 employees, who produced the first bearing on the 17th June.

By the outbreak of World War I, the number of employees had increased to 250, and 3,500 bearings were being made each week. During that war, the size and output of the factory was doubled, and more land was bought. Between the wars, the story was one of almost continuous expansion, to meet the demands of the automobile and other industries, and by 1930 the average weekly production had risen to about 60,000 bearings.

An important step was taken in 1936: since no further extension was possible at Luton, land for more premises was bought at Sundon, 2½ miles away. During the Second World War, the number of employees rose to more than 3,000 and production was stepped up to about four times the 1930 figure. The first productive sections of the Sundon factory were built during the war period, in 1942, as a measure to safeguard production. Development of the site began again in 1946 and has continued until the present day. This factory is now, in fact, over twice as large as the older one, and the combined floor area of the two is more than 80 times that of the original shops of the factory in Leagrave Road.

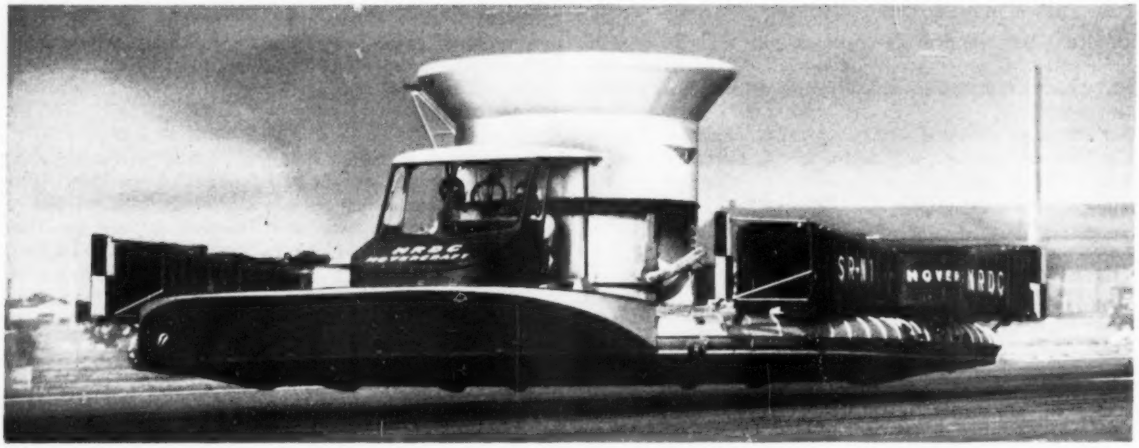
It is a point of some historical interest that a Skefko advertisement was among those to be published in the first issue of *Automobile Engineer*, in 1910.

Moss Gear Co. Jubilee

ANOTHER company celebrating its Golden Jubilee during 1960 is The Moss Gear Co. Ltd., of Crown Works, Tyburn, Birmingham 24. This well known concern was founded in 1910, and then occupied a small factory in Aston. Although various extensions were made as the business expanded, it became evident during the 1920's that a new and larger site would have to be found. A move was, therefore, made in 1928 to the present site, which is further out from the centre of the city.

At that time, the Erdington district, in which Tyburn is situated, was still largely rural, and the purchased area of about 15 acres allowed plenty of space for additional expansion. Since the second factory was built, numerous extensions have been made to the machine and fitting shops. A relatively recent addition has been a large and well equipped drop stamping shop.

The name of The Moss Gear Co. has always been closely associated with the motor industry, but activities also cover the agricultural and general industrial fields. In addition to the familiar Moss products—gearboxes and complete axles for rear-wheel and front-wheel drive—the company is now manufacturing propeller shafts and universal joints, the output of which is mainly for use on agricultural implements.



THE NEXT FIFTY YEARS

An Analysis of the Probable Trends of Development, as Indicated by Influences and Pressures Likely to be Brought to Bear upon Design

BECAUSE of the vast amounts of capital at stake and the serious social implications of failure to plan effectively to meet contingencies, those responsible for overall control of engineering development are having to look ever further into the future. Perhaps it is not always fully appreciated that great manufacturing organizations could virtually collapse in the course of a year or two if they were to be caught unawares by a radical change in the technical scene. For example, the widespread introduction of gas turbine engines for cars would leave without means of livelihood those firms who specialize in the manufacture of only valves or piston assemblies; alternatively, the adoption on a large scale of hovercraft could have a similarly disastrous effect on those who make tyres and wheels. Apart from the danger of drastic changes, there are also the perhaps less serious, but nevertheless more insidious ones, of gradual evolution and changes in fashion and technique, and it calls for the exercise of foresight, though over shorter periods of time, in order to keep a manufacturing organization sufficiently far ahead of these impending changes.

Some of the ideas propounded in this article may to-day sound far-fetched. However, it is perhaps pertinent to speculate as to what might have been the reactions of our readers fifty years ago had we suggested to them that in 1960, aircraft would be travelling at two or three times the speed of sound, space vehicles carrying instruments would be sent in orbit round the moon and the sun, that nuclear powered submarines would be encircling the globe, fully submerged for practically the whole journey, and without refuelling, and even that internal combustion gas turbines operating at speeds of the order of 50,000 r.p.m would be in the advanced stages of development for road vehicles. In fact, experience has shown that short term predictions generally over-estimate the progress that will be made, whereas long term ones under-estimate it.

In order to align production and design policies in a logical manner for operations in a planned sequence, if possible without major changes of direction right through to the distant future, it is necessary first to examine the long term problems; these are most likely to be influenced by drastic changes that are difficult, and in many instances impossible, to foresee. In this connection, it is hardly possible to plan for the advent of, for example, a completely revolutionary form of propulsion, which might arise, perhaps from some fantastic development such as the harnessing of electrical energy from the outer atmosphere or from space. From that thought we, therefore, are obliged to come down to earth and study the problem from first principles in relation to the various factors that are likely to have a powerful influence on engineering trends.

Power units

Apart from the structure required to carry the occupants of a car in comfort and safety, there is only one essential component of a motor vehicle, and that is the power unit. Therefore, this is the first to come under examination. The essential requirements of this unit are:

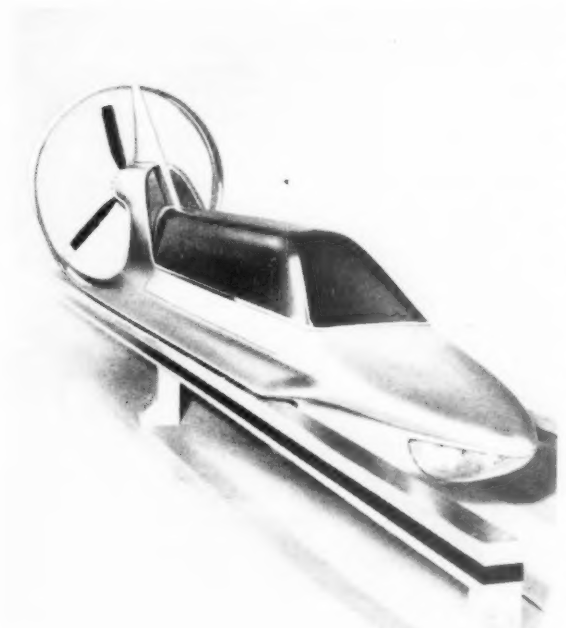
(1) Low cost
(2) A high output relative to its bulk
(3) High power : weight ratio
(4) Economy of operation
(5) Reliability
(6) Silence and freedom from vibration
(7) Absence of any hazard to health

In respect of the last three of these requirements, current engines of the conventional reciprocating type are acceptable in our present-day vehicles although they can and will be further improved by detail development. Therefore, there is not likely to be any great pressure leading to change on account of these.

With regard to economy of operation, a lot remains to be desired. Because of the thermodynamic losses inherent in the Carnot and other cycles, and the mechanical and other losses in an engine, any development that can obviate the heat engine for the production of power from fuel will be welcomed. It is this factor that is the principal force

motivating research on fuel cells. Basically, the fuel cell is a reversal of the principle that is applied in the electrolysis of, for example, water. It is well known that if an electric current is passed through water, oxygen is given off at the anode and hydrogen at the cathode. In the reverse process, when oxygen and hydrogen combine, the chemical action is accompanied by the production of electrical power. This is not a new discovery: Sir Humphrey Davy first examined the possibility of a fuel cell comprising carbon and nitric acid about 150 years ago. The advantage of the process is that it is possible to produce electrical energy from the chemical reaction without using an engine and generator.

Neither the Saunders-Roe Hovercraft illustrated on the opposite page nor the American Ford Levacar below represent possible successors to the road vehicles of today. The Hovercraft, however, used as a high speed ferry, to form a cross-channel connecting link between the Continental motorway system and that in the British Isles, could become a useful adjunct to long distance international road transport



The fuels can be any of a number of chemical compounds or elements: the basic requirements are at least one oxidant and one reductant. Examples of the former are oxygen, air and chlorine, and of the latter, hydrogen, carbon monoxide, certain hydrocarbons, zinc and magnesium. The advantages of such a power source are likely to be the very small number of moving parts, and its ability to withstand vibration, shock and extremes of climatic conditions. Its disadvantages at the present stage of development are large overall bulk and the large number of cells needed; possibly, however, research will lead to a reduction in bulk.

So far as number of parts is concerned, an experimental unit installed in an Allis-Chalmers tractor comprises 1,008 individual fuel cells. The fact that these fuel cells are all identical and could be very simple must, however, be taken into consideration, since they could be produced easily in very large quantities and, therefore, at a low cost. This tractor, which operates on a mixture of gases, largely propane, is claimed to give a drawbar pull of at least 3,000 lb, and its control is simply a matter of employing an electric switch arrangement to place the four banks of cells in series or parallel, in different combinations, and thus to vary the amount of current going to the d.c. motor. Reversing is simply a matter of changing the polarity of the current flow to the motor. Of the fuel cell, it can be said that is a promising development, because it can be operated on fuel that, if produced in large quantities, will probably be no more expensive, and could conceivably be cheaper, than conventional hydrocarbon fuels, and the production of electricity could be effected at a relatively high efficiency. However, it will be acceptable as a car power unit only if some way is found of drastically reducing its bulk, a development which at present cannot be foreseen.

It is unlikely that, in the next fifty years, any fuel for conventional engines will be developed that is much cheaper than the hydrocarbon fuels used to-day, unless we learn from research into atomic structures some way to synthesize, inexpensively, elements and compounds. A possibility is, of course, that nuclear power units might be developed. The latter can, however, probably be dismissed on the grounds that, where atomic energy is used, there is a danger to health, from radiation, and this danger can only be guarded against by heavy masses of shielding material or extremely complex and costly electronic equipment. In other words, the power: weight and power: bulk ratios of a safe unit would almost certainly be too low for application to road vehicles. A significant factor, so far as the development of synthesized fuels is concerned, is that in fifty years' time the rate of consumption of hydrocarbons will be so high that we shall be anxiously surveying world reserves of crude oil to see how much longer they will last.

Engines based on rotary motion

This brings us back to the internal combustion engine. It has always been obvious that a rotary type of engine, as opposed to the reciprocating type, would almost certainly be less trouble from the maintenance point of view and would be relatively vibration-free by comparison with conventional motor vehicle engines currently employed. The first type of rotary engine that comes to mind is, of course, the gas turbine. In its early stages of development, on account of its extreme basic simplicity, it seemed to be most promising. However, it is now well known that it is unlikely that the specific fuel consumption can be reduced to an acceptable value without recourse to a heat exchanger; moreover, the simple compressor-turbine arrangement has disadvantages so far as torque characteristics are concerned, and the employment of two turbines, one to drive the compressor and the other to provide the power output, further complicates the engine.

Development of this type of engine for road vehicles has now reached the stage where, from the point of view of rate and smoothness of acceleration, the gas turbine powered car is at least as good as, if not better than, any conventional one. Fuel consumption still has to be reduced before it can be regarded as competitive, and it is unlikely that the turbine will be adopted in practice for at least seven years, and even then only for special applications such as racing cars and, possibly, heavy commercial and public service vehicles. The incentive for the development of the turbine is its potentially high power: weight and power: bulk ratios, and its other advantages now lie not in simplicity of the power unit but in the obviation of the need for a clutch and gearbox, and potentially long life between overhauls.

Another rotary engine that shows promise is the Wankel unit, currently being developed by N.S.U. and the Curtiss-Wright Corporation. This was discussed in detail in the May 1960 issue of *Automobile Engineer*. In this engine, the four cycles, induction, compression, expansion and exhaust, are effected during one revolution of a rotor in an epitrochoidal chamber. Sealing problems apparently have been solved; however, the development is far from complete

and it remains to be seen whether the combustion characteristics can be further improved and the brake specific fuel consumption reduced to an acceptable figure. Success appears to be within the grasp of the men who are developing this unit, and it would be a great pity if after all their efforts it were to elude them. The principal advantages of this type of engine are its compactness and low weight relative to its power output, its simplicity and, because of its rotary mechanism, freedom from vibration and the other well known shortcomings of reciprocating type engines. We should know within the next five years whether it is going to be a success.

Hovercraft

We now turn our attention to the components that are second in order of importance on the vehicle, namely the wheels. That these are by no means essential has been proved by the recent introduction of hovercraft, which operate at a height of between a few inches and a few feet above the ground. Although it is obvious that the engine-compressor installation needed to raise the craft on a cushion of air and to propel it must inevitably be more costly and complex than a conventional power unit, this is, at least to some extent, offset by the complete elimination of tyres, wheels, suspension and transmission.

The air cushion can be likened to an inertia-less suspension system, and the vehicle should, therefore, give an exceptionally comfortable ride. Also, other than the aerodynamic drag, there is little resistance to motion, so the propulsive efficiency inevitably will be high and the vehicle could operate at very high speeds. However, as the plan area of the vehicle is reduced, the ratio of that area: the periphery of the air cushion, that is the length of air seal needed, increases. Therefore, the efficiency of this type of vehicle increases with size. This, coupled with the fact that it is difficult to see how hovercraft could be steered accurately enough for high-speed operation on roads of even moderate width, makes it unlikely that they will be used as road vehicles. Moreover, vehicles of this type could not be operated across country, except in undeveloped areas: in this connection, there is not only the problem of avoiding damage to crops, but also that of the dust that would be raised. It seems likely, therefore, that this type of vehicle will be applied only for special purposes and it could be particularly useful for operation over water.

Another type of vehicle that could be operated on an air cushion is a monorail car or public service vehicle. One advantage of this is that the area of the air cushion would be small and, therefore, the size of air compressor required correspondingly small. As in the case of the hovercraft, the resistance to forward motion is only that originating from aerodynamic drag, and, therefore, the vehicle would be capable of very high speeds. However, its restriction to operation on a rail—and such vehicles might also operate on two rails—places it under the same disadvantages as are conventional railway systems. It could, nevertheless, be developed for the transport of people daily to and from work in large towns and cities. In fact, such a development might be forced upon us by the pressure of increasing population and sizes of built-up areas. It is more likely, however, to be used for relatively long distance, that is, inter-city travel.

Road trains

A potent factor in the future development of road vehicles will be the ever increasing density of traffic on the roads. This leads to consideration as to whether these roads could be used more efficiently. One sees on the railways very large numbers of people and very large quantities of goods carried at reasonably high average speeds over long distances. The advantages of the railway system are that in most instances there is only one power unit for perhaps eight or more vehicles—the carriages or wagons. This system has the disadvantage that it cannot carry either goods or passengers from door to door and, in the more general sense, it lacks flexibility since they must all go to one of a series of fixed destinations.

It is not beyond the bounds of possibility that road vehicles could be modified in such a way that they can have some of the advantages of the railway systems without their disadvantages. An indication of how this could be done was given in the leading article of our December 1959 issue. Basically, the idea is to incorporate an electronic control system in the road and to equip each vehicle with a receiver unit. With this arrangement, vehicles could be driven at high speeds under automatic control over long distances. It seems likely that it would not be practicable, from the point of view of economics, to install such control systems in roads other than motorways and on selected trunk routes. Even so, it could be of great value for commercial vehicle operation. As to whether private cars would make use of it, that would depend upon the extent to which roads were equipped and the cost of the electronic units to be installed in the vehicles.

By the use of automatic control, routes carrying heavy traffic could be used at optimum efficiency, with all vehicles travelling at a uniform high speed. In the event of a vehicle's breaking down, those following would automatically be signalled to slow down or stop until the defective vehicle were off the road and on to a hard shoulder. There would be no loss in respect of flexibility since transport would be effective from door to door. As for the prospects of this system, one would expect it to be under serious consideration in this country perhaps as soon as thirty years hence. In the United States, because of the density of traffic on trunk roads radiating from the cities, it could even be in operation by that time.

Shorter term prospects

One of the decisive factors that will influence development over the next fifteen years and more is the ever increasing density of traffic on the roads, brought about by the rising standard of living, and the development of motorways. With regard to the latter, despite the already extensive systems in existence on the Continent of Europe, we can envisage a further development, and that is the extension of these motorways on an international, as opposed to national, scale. The result will be that road transport vehicles will be more widely used for very long distance travel. With this factor in mind, one can foresee that the development of motor cars in Europe may follow that which has for many years taken place in America. In other words, the accent would be on the evolution of larger cars and softer suspension systems to give more comfort in high-speed travel over long distances. This development would also imply the use of engines of higher output, operated at a lower power factor —the more powerful engines would, of course, give more effortless cruising and would be less noisy than our present-day units operating relatively close to the upper limit of their rating. On the other hand, this trend towards larger vehicles and more powerful engines will be limited by the demand for fuel economy as the rate of consumption throughout the world increases. In any case, reduction of aerodynamic drag of vehicle will become more important than hitherto.

It is necessary also, of course, to take into consideration the increasing density of traffic in towns, and the consequent pressure for smaller cars and good manoeuvrability and acceleration at low speeds. There inevitably will come a stage where, because of rising standards of living, many families will have two cars. In those circumstances, the

choice would probably be between, on the one hand, two town cars of small size and, on the other, one small and one large car; it is hardly likely that a very significant number of people would have two large cars.

Obviously, the increasing density of traffic on the roads will be a very powerful incentive for the development and operation of helicopters and vertical take-off aircraft to take the place of buses and coaches. This, however, can only follow the extensive provision of landing and take-off areas, perhaps on the roofs of buildings, and could hardly be expected to be in operation until the very end of the fifty year period that we are considering in this article. In fact, a prerequisite would be a much more highly organized society than we are likely to have within that space of time.

The development of very long distance trunk roads on the Continent could have a serious impact on the motor industry in Great Britain, where, of course, distances are limited by the fact that we are a relatively small island. Unless at least one major route for road transport, by tunnel, to the other side of the Channel is made available or large hovercraft become available for use as high-speed ferries, the demand in this country will remain for the smaller types of car that are in common use to-day, and this could affect the prospects of the British industry in overseas markets.

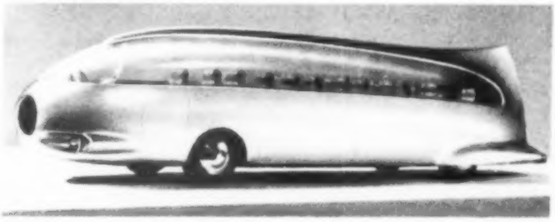
Another change in overall conditions that will have an important bearing is the steadily rising cost of labour in respect of maintenance; so design for ease of servicing will become a most important factor. One result is almost certain to be that many of the component assemblies will be manufactured on the basis that they do not require any servicing, but are simply exchanged for new ones and thrown away when they become defective. This trend will be hastened by the introduction of automatic assembly machines with the consequent employment of devices other than nuts, bolts, screws and rivets for securing parts together.

PROSPECTS IN RESPECT OF THE PRINCIPAL ASSEMBLIES OF THE VEHICLE

With regard to the likely course of progress in respect of the major assemblies in motor vehicles, there is probably only one uncertain factor that could have far reaching consequences, and that is the possibility of the widespread adoption of the N.S.U-Wankel type of engine. On this subject, as has already been mentioned, we shall be able to be more certain within the next five years. Apart from this, it can safely be assumed that development will follow lines already apparent and will take the form of detail improvements of conventional components and, possibly, some shifts in emphasis with regard to overall layouts.

Engines

On the assumption that the reciprocating type engine will still be the universally used prime mover, it seems likely that, in Europe, compression ratios will be of the order of 10 : 1 for petrol engines by the time ten years have elapsed, and that subsequently, in view of the many problems to be faced and the relatively small advantage to be gained, there will be no point in increasing the ratio above about 12 : 1. Engine speeds will continue to rise gradually, and valve gear



The widespread introduction of roads such as the London-Birmingham motorway illustrated on the left will certainly lead to careful study of the aerodynamics of vehicle design, in respect of both drag reduction and stability, and it could easily result in the development of coaches similar to the Viberti prototype above, which was made in 1956

design, which already presents some serious problems, will certainly have to be improved and may well be radically changed. The increasing engine speeds and larger valves, and consequently stronger springs, will so aggravate the tappet wear problem that positive steps will have to be taken to remedy the shortcomings in this respect.

There can be no doubt that once the tappet clearance becomes incorrect, the rate of wear is accelerated, and in this connection, it is of interest that American engines are generally equipped with hydraulic automatically adjusted tappets; however, these, too, are not without their problems. Perhaps the overhead camshaft layout will be the answer to current problems. High compression ratios inevitably will entail compact combustion chambers, and the wedge type has much to commend it. There is every prospect that light alloys will be used extensively for cylinder block and crankcase castings within the next ten or fifteen years. The most promising fields for exploration are those of stratifying the charge in the cylinder and varying the compression ratio to improve part-throttle efficiency.

Diesel engine speeds will increase during the next fifteen

years to the point where they will not be so very different from those of current petrol engines. Higher speeds will cause designers to pay special attention to the lightening of moving components, and light alloys will be more widely used for the main castings. The two-stroke diesel engine has many attractions to offer and it would not be surprising if, before the end of the fifteen year period, the proportion of two-stroke engines in use has not increased. The opposed piston layout has much to commend it, and is particularly well suited to multi-fuel operation, which could become an important factor.

Air cooling, either for petrol or diesel engines, is especially attractive only for countries that have very cold climates. A principal advantage of air cooling, so far as the manufacturer is concerned, is that, by the employment of identical cylinder and piston assemblies with different crankcases and crankshafts, a series of engines can be produced to cover a range of requirements in respect of power output. However, the advent of turbocharging provides an alternative that is almost certain to be adopted for diesel engines, to obtain increased power output for applications requiring it. In general, because of cooling difficulties, it is not practicable to rate air-cooled engines very highly when they are installed in road vehicles.

So far as liquid cooling of both petrol and diesel engines is concerned, more effective control over the systems can be expected: too much power is currently wasted in driving the fan, which also can be noisy. In commercial vehicles especially, the demand for the economical use of space will lead to the adoption of more efficient, fully-shrouded fan and radiator installations.

Transmissions

Towards the end of the next fifteen years, automatic transmissions for cars will almost certainly be the general practice in Europe. The question as to whether they will incorporate torque converters, on the lines of those already in large scale production in America, or whether hydraulically or electrically actuated clutches will be the basis of the designs, remains to be resolved; there is also the possibility that some other form of hydraulic drive will be employed. Electronic controls for automatic transmissions should also receive serious consideration, and this would appear to favour the electrically operated clutch arrangements. Until recently, because of the inherent shortcomings of the thermionic valve, electronics were expensive, unreliable and bulky; however, this situation has been changed by the advent of the transistor and printed circuit.

With the coming of automatic transmission, there is a very strong case for separating the transmission from the engine, and incorporating it in the final drive unit. In this way, weight distribution can be improved, by having the engine at the front and the whole of the transmission assembly at the rear, and the height of the propeller shaft tunnel reduced. For small cars, however, the front wheel drive layout will probably be favoured. The rear-engine, rear-wheel drive layout has too many serious disadvantages: the main ones are, of course, instability so far as handling the vehicle is concerned and inadequate space for luggage. However, the possibility of installing the engine under the rear seat should not be overlooked.

On public service vehicles, there could easily be a trend towards the employment of under-floor engines at the extreme rear. This tends to relieve the front wheels of some of the load and thus to lighten the steering. Moreover, the weight of the engine, with this arrangement, is better carried on the twin-wheel equipment at the rear. With the engine under the floor in this position, there is no loss of carrying capacity within the body, and the transmission line is short. The principal disadvantage, of course, is the remoteness of control, although this, as in the case of passenger cars, could be offset by the employment of automatic transmission, which should become widespread within the next fifteen years. For public service vehicles, the hydraulic torque converter, or the fluid flywheel used in conjunction with a Wilson type gearbox, and electric automatic control, will obviously be used because of the inherent sturdiness of these units and their smoothness of operation under

conditions of heavy load. Automatic transmissions are not likely to find favour for very many years for goods-carrying heavy commercial vehicles, except in special applications.

Suspension, steering and brakes

On the subject of suspension for cars, the changes in engine and transmission layout already mentioned will entail an increase in the number of vehicles with independent suspension on all four wheels. It would appear that the only prospect of improving springing economically is that of obtaining a variable rate, and this can most easily be done by the employment of rubber. In this connection, the B.M.C. organization has pointed the way with the system adopted on the ADO 15 model. Air suspension is too complex for use in cars under present conditions, although the advent of power operated seat and window adjustment could change the situation; the latter amenities are not to be expected, however, except in the most expensive cars, for at least ten years.

There is another direction in which there is room for improvement and that is in suspension dampers. Well before fifteen years have passed, we can expect to see on the more expensive quantity-produced cars, facilities for adjust-

Traffic conditions like those in the illustration at the foot of the opposite page are commonplace in our cities today, and the situation will inevitably become worse. This will surely force public service operators to use vehicles that will take to the air. The Fairey Rotodyne above is representative of a possible solution, but vertical take-off jet craft have greater scope

ment of the dampers by the driver while the vehicle is in motion. On all classes of commercial vehicle, too, suspension dampers will probably be improved by the incorporation of facilities for their adjustment. This will be particularly necessary with air suspension, since the requirements for the laden and unladen conditions differ widely.

For commercial vehicles, there are prospects for the widespread use of air suspension within the next seven years for public service vehicles, tankers, trailers and semi-trailers, and possibly even for trucks. In the same period, there will certainly be a wide extension of the use of independent front suspension, particularly on the lighter types of vehicle up to about two tons capacity and on all public service vehicles. Front-wheel-drive layouts will probably become popular for light commercial vehicles. Accompanying the introduction of independent suspension on the lighter commercial vehicles, there are likely to be parallel developments in the form of torsionally stiff chassis frames, with side and cross members of box section. Welding—probably carbon dioxide shielded, on an automatic production basis—will be used for the frame construction.

It is reasonable to suppose that power assisted steering will be in widespread use, especially for public service vehicles, by the end of the next fifteen or twenty years. For cars, there is not much to be said about steering. By the time fifteen years have passed we can expect power assistance to be used widely on the more expensive quantity-produced cars. Apart from this, conventional systems will have been improved so that they have the precision that will be needed to cope with conditions arising in heavy traffic and at high speeds.

There really seems to be no reason why spare wheels, as we know them to-day, should not be dispensed with for private cars. Benefits would accrue in respect of not only space saving but also cost. It should be possible to devise some sort of inflatable device that occupies very little space and which can be quickly fitted to or in place of a wheel, the tyre of which has been punctured or burst; this device would only need to be used as a get-you-home measure.

Although there is still a lot of development work to be done on disc brakes, it is to be expected that the current rate of progress will continue and they will steadily supplant the drum type, beginning with the heavier and the faster cars and gradually extending down the range. As the production of disc brakes gets into its stride, and they therefore become less costly, there will be a tendency for them to oust the drum type completely, probably for the sake of rationalization. This process might be expected to take about twenty years.

With regard to brake servo control units, the current trend is likely to continue and they will become increasingly popular. This is not only because of the modern tendency to supply power assistance for all controls, to reduce driver fatigue, but also because the disc brake is comparable with the two-trailing-shoe type, in that it has no inherent servo action. Although it is possible to obtain servo action with disc brakes, this will increase the severity of thermal loading and complicate the assembly, so it will not be used if it can be avoided.

On heavy commercial vehicles it is likely that the course of development will follow that which is already being experienced in respect of private cars. Disc brakes will be used at first on the front wheels, and there are several reasons for this: at present, too high a proportion of the braking is generally being effected on the rear wheels and the employment of disc brakes on the front could remedy this situation; also, there might be some difficulties with disc brakes at the rear, especially if they were used in such a way that they dissipated more energy than the conventional drum type brakes already fitted. The reason for this is that with twin-wheel equipment there is difficulty in dissipating the heat generated. The situation is at its worst on public service vehicles and pantechnicons because of the shrouding of the wheels by the bodywork. The difficulties likely to be experienced as a result of excessive build-up of heat are damage not only to the tyres but also to oil seals; in addition, there is a tendency for grease in axle bearings to melt and to be lost. Hand brake operation is also a problem with discs.

Automatic anti-skid devices, which prevent the locking of the wheels when the brakes are applied hard, are so very effective as a safety factor that they are likely to become standard equipment, at least for certain types of vehicle. Another useful automatic control that will probably become accepted is the type that distributes the braking load to the front and rear wheels in proportion to the loads on them.

Bodywork and miscellaneous

Competition will force improvements with regard to anti-corrosion measures and general finish. Already chromium plate is being ousted by the employment of stainless steel and aluminium, and this trend will continue unless better

plating methods are developed, which, however, is unlikely since plating is inherently an expensive process if done really well.

There is a possibility that alternative materials of construction will be used, although this is unlikely to happen within the next fifteen years. The development of reinforced plastics as a material for body panelling depends largely upon whether the moulding processes can be mechanized and the length of time required for curing drastically reduced. So far, there is no sign that either of these developments will occur in the near future, but if they do it is likely that the next step forward will be the introduction of techniques for embodying metal structural sections in the moulded plastics, for the purpose of load distribution.

Among the miscellaneous features that must be considered is chassis lubrication. In fifteen years' time, attention every 1,000 miles or so with a grease gun will be virtually a thing of the past, and only the engine and transmission will be required to be topped up with oil. The design of all components of the vehicle will be influenced by the introduction of automatic production: dovetailing, keying, peening and swaging will be used on an ever increasing scale to replace the bolting together of components. With regard to welding, the principal significant change to be expected is the use of carbon dioxide and other gas-shielded electric arc welding processes, because of their suitability for automatic production.

More attention is likely to be focused in the coming years on the design of engine transmission and suspension components to form self-contained front and rear sub-assemblies, as on the B.M.C. ADO 15 car. This will have very great advantages from the point of view of rationalization, in that different types of body—both car and commercial vehicle—can be fitted with common major mechanical components.

In this and the preceding six pages, we have ventured to prophesy what will be the major trends in the coming years. Although none of our editorial staff is likely to be here at the end of the period we have covered, we of course hope to see, as many of the years go by, the accuracy of our forecasts confirmed; and to those who will be reading this article again in preparation for the centenary issue of *Automobile Engineer*, we say: have another try, and the best of luck.

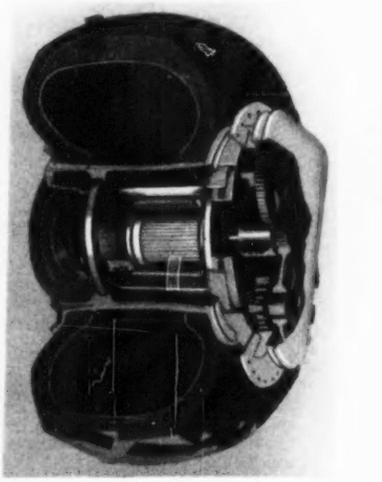
Large Motorized Wheel

FOR cross-country work, a vehicle having an independent power supply to each wheel should have superior traction and manoeuvrability to one with conventional all-wheel drive. Various attempts have been made in the past to provide an independent system, but they have mainly been directed at the smaller type of vehicle. However, the motorized wheel developed by The International General Electric Company's Locomotive and Car Equipment Department, Erie, Pennsylvania, U.S.A., is designed for very large vehicles operating in difficult terrain.

Housed within the hub of this wheel is an electric traction motor and an epicyclic reduction gear. Since the motor develops 380 b.h.p. at the wheel rim, a four-wheel vehicle embodying the system would have a total power of 1,520 b.h.p. Normally, the current for the motors is supplied by a diesel-electric generating plant carried on the chassis, but an overhead supply can be utilized in special circumstances. The hub is fitted with a tubeless tyre of 10 ft diameter.

A speed-sensitive control device is used to ensure maximum traction: if one wheel loses grip, the current to that wheel is automatically reduced, and more is fed to the other wheels. The regenerative braking system, in which the motors act as generators during deceleration, provides highly effective retardation without risk of fade. Resistors convert into heat the electrical energy generated during braking.

Apart from its advantages in respect of traction, manoeuvrability and braking, the system is claimed by the manufacturers to have a high overall efficiency and to involve less maintenance than is needed on an orthodox vehicle. Other benefits are freedom from stalling when a sudden excess load is encountered, unusually good hill climbing abilities, and greater freedom for the vehicle designer, because of the absence of propeller shafts, transmission casings and gear-change mechanism.



In essence, the large motorized wheel made by General Electric comprises a traction motor of 380 b.h.p. in the hub, and a system of epicyclic gearing

Measuring Exhaust Gas Temperatures

FOR THE measurement of exhaust gas temperatures in diesel engines, a new pyrometer has been introduced by Savage and Parsons Ltd., Watford, Herts. Although intended primarily for the larger types of stationary and marine engines, it is also suitable for smaller power units. The pyrometer can be used to indicate temperatures either at the cylinder head ports or in the exhaust manifold. It comprises up to eight iron-constantan thermocouples, mounted in stainless steel sleeves, and a meter of the moving-coil type. This meter is specially designed to withstand vibration and can be mounted on an instrument panel.

There are eight pairs of terminals on the back of the meter, so all the thermocouples can be connected to it. The use of a nine-position selector switch, which includes an off position, enables a reading to be taken from each thermocouple in turn. A zero adjustment, to allow for different ambient temperatures, is incorporated in the meter: since it is beneath the selector switch, it cannot be tampered with unless the switch is removed. Once the zero has been set, changes in ambient temperature are automatically compensated by means of an internal bi-metal strip.

The scale reads from 0 to 1,600 deg F, and the maximum accuracy of the meter is obtained in the region of 1,200 deg F. Leads of 22 s.w.g. wire connect the meter to the thermocouples, and the instrument can be calibrated for any desired lead length up to 50 yards. For longer lengths heavy-gauge compensating leads would have to be used.

Carburation and Performance

Part I. A Review of Engine Requirements in Respect of Fuel-Air Mixture Supply

CHARLES H. FISHER,* M.I.Mech.E., M.S.A.E.

IN reviewing the phases of engine development over the last quarter of a century, one cannot fail to be impressed by the steady improvement in power output in terms of peak b.h.p/litre, and also in respect of torque output over the middle of the speed range. It is not an exaggeration to say of the mass-produced car engine that, in general, the b.h.p. developed per litre swept volume has been doubled in twenty-five years. To keep pace with this increased output, great demands have been made upon the accessories, one of the most important of which is the carburettor. Since indicated horsepower is directly proportional to the weight of air consumed, any increase in power output of an engine of a given swept volume requires larger valves, ports and induction tracts, together with higher valve lifts, and a larger carburettor venturi.

To double the peak output it may be necessary to double the venturi area, and although this in itself presents no problem to the carburettor manufacturer, it may have repercussions in respect of the low-speed performance of the engine. High standards of flexibility, for driving in traffic, are now expected, and even sports cars have to be capable of being accelerated without hesitation from low speeds. The carburettor engineer is thus faced with the necessity for venturi and air passage areas that will satisfy the requirements in respect of not only high power at high r.p.m, but also smooth running and acceleration at low speed.

Increasing the size of the venturi, of course, has the effect of reducing the speed of the airflow through it at low engine speeds, with a consequent loss of head in the fuel metering elements of the carburettor. As a result, the fuel is less well atomized and there is some weakening of the mixture as delivered to the cylinders. A sudden transition from closed or nearly closed throttle to a fairly wide open one, for acceleration, can result in hesitation in torque, or what is commonly known as a *flat spot*. Owing to the sharp increase in absolute pressure in the induction system under these conditions, some of the fuel droplets carried, in suspension, along with the air are precipitated and deposited on the walls and floor of the induction tract.

Too often, in the pursuit of more and more volumetric efficiency and power at high speed, the hot-spot is either discarded altogether or greatly reduced in effectiveness. This is done regardless of the fact that in most instances the gain in peak power as a result of the reduction in heating is very small indeed and is more than offset by the disadvantages entailed in respect of loss of flexibility and acceleration for getting away in traffic.

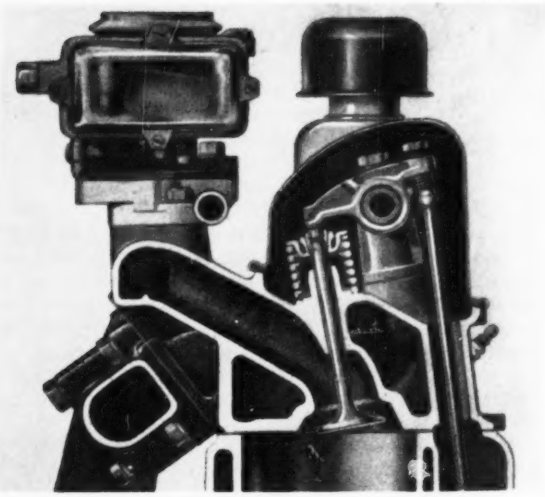
It is well known that with engines in which the disposition of the valve ports necessitates the employment of the engine coolant for heating the mixture, the warm-up time must be longer, and in some instances is a good deal longer, than that of those with exhaust gas heating. But it is, perhaps, not so widely appreciated that when modern efficient heaters, for the car interior, are in operation, the delay in warm-up of the engine can be even more serious. This naturally leads one to conjecture on the possibility of employing the combustion type of heater, similar, for example, to that employed on the Chevrolet Corvair, for the interior of the car. In very cold climates, such a unit might be also used to supply heated air to the carburettor air intake for cold starting and during the warm-up period. There is also the possibility of drawing the air from the vicinity of the exhaust manifold when the engine is cold, and from a cool area when it is hot, Fig. 1. This scheme is extensively employed on Continental cars, good examples being the Fiat 600 and 2100 models. By means of a simple manually operated flap or rotary valve, a seasonal adjustment can readily be made for summer or winter conditions.

An even more advanced system is that of the Lincoln, in which the air entering the carburettor is regulated by a thermostatically controlled flap valve, so that warm air is supplied until the engine has attained working temperature. In addition, a three-stage thermostat is incorporated in the coolant system, to avoid the large drop in cylinder head temperature that would otherwise occur as a result of bringing both the cylinder block and radiator into the circulation simultaneously.

In previous years, the line of demarcation between the performance of the mass-produced saloon and the sports car

Fig. 1. The intake to the air filter on the Fiat 600 car is fitted with a control that, in winter, permits the air to be drawn from the region of the exhaust manifold; in summer, air is taken through the holes which are around the upper part of the periphery of the filter body

*Zenith Carburetter Co. Ltd



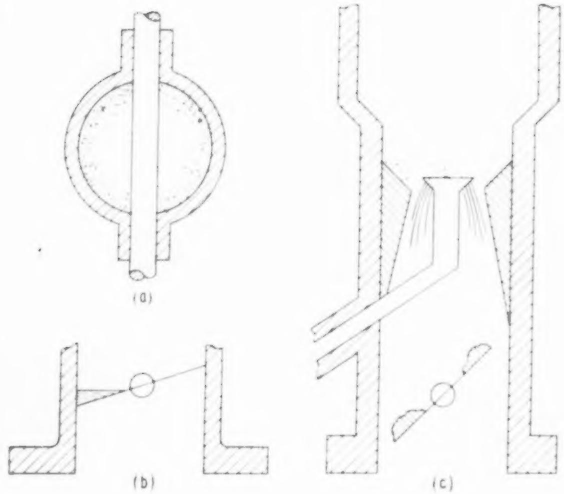


Fig. 2, right. Carburettor icing has recently become prevalent again. It can occur on the throttle butterfly, as shown in (a) and (b) or in the venturi, as in (c); in the latter form, it can be sufficiently serious to bring a vehicle to a standstill. Fig. 3, left. To reduce the likelihood of icing, the throttle body of the downdraught carburettor of the new American Ford Falcon compact car has a water jacket and is heated by the engine coolant

was clearly defined. While such division still exists, the gap has narrowed a good deal. It may well be that at some time in the future it will be found impossible to serve the high-performance engines satisfactorily with the conventional open-choke carburettors, or even with the constant-vacuum type. Perhaps British manufacturers will follow the lead of American and Continental ones in the development of compounded twin- or even four-barrel open-choke carburettors.

Alternatively, the constant-vacuum type of carburettor might be superseded by some arrangement of the compounded open-choke variety, or possibly by a combination of constant-vacuum and open-choke designs. It is perhaps significant that on a number of racing engines, with very high power outputs, twin-barrel open-choke carburettors are employed in such a manner that each throttle barrel feeds one cylinder. The fact that these instruments generally are of Italian origin does not mean that other manufacturers are incapable of designing such carburettors: it is simply that the demand is not large enough to justify the expense of tooling for production.

Economizer carburettors

Many modern open-choke carburettors incorporate a mechanical device to weaken the mixture automatically for economy under part-throttle cruising conditions. Here again, adequate heating of the mixture is essential if the best use is to be made of the economy system. Most important, also, is the quality of distribution between the cylinders. Indeed, distribution is one of the factors having most influence upon the ability of an engine to burn weak mixtures at part throttle, for it is the cylinder receiving the leanest mixture which will determine the weakest setting that can be used. Any good economy carburettor can supply as lean a mixture as the engine can burn.[1]

Economy carburettors have brought in their train the need for an acceleration pump. When the engine is operating in the economic cruising range, sudden opening of the throttle would almost invariably be accompanied by some hesitation in torque output were it not for the inclusion of a pump to inject a small metered quantity of liquid fuel into the ingoing airstream. In most instances, the pump piston or diaphragm is interconnected with the throttle spindle; in others it is operated by induction depression. It is perhaps appropriate at this point to expose a common fallacy: this is the belief that any acceleration pump arrangement must of necessity be wasteful of fuel. This certainly is not so: it has been fully established by extensive tests that an efficient carburettor incorporating an economy device and pump, and properly adjusted for a particular type of engine that is capable of running on lean mixtures at part throttle, will return a better fuel consumption on the road than a similar type of carburettor without these devices. There are some car engines, particularly among those with four cylinders, which because of their combustion and other characteristics, cannot operate with weak mixtures under part-throttle conditions.

Constant-vacuum type carburettors also require enrichment under acceleration conditions. On a well known one this is done by damping the upward travel of the piston and fuel metering needle, by means of a small oil dash-pot arrangement. During acceleration, the piston assembly tries to rise under the influence of the increasing airflow. The dash-pot slows down this action, however, with the result that the depression across the jet orifice is increased and the mixture enriched until the piston has risen to its position appropriate to the airflow at the moment.

Short downdraught carburettors

One of the design problems that has engaged the attention of carburettor manufacturers in recent years has been the reduction in height of downdraught carburettors. This is of course the result of the lowering of bonnet profiles, which severely limits the space available for the accommodation of the carburettor. Possibly this reduction in space available below the bonnet will bring about the reintroduction of the horizontal type of carburettor in open-choke form. However, although this is well within the bounds of possibility, there is every indication that before long there will be just as little space around the sides of the power unit, as more accessories are crammed into the engine compartment.

When the downdraught type of instrument was introduced into this country from America, in the early 1930's, there was a good deal of indecision and criticism. One commonly held belief was that the carburettors would flood and engines be ruined. In an article by the author, published

in 1933 in *Automobile Engineer*[2], it was stated, "Fashions even in motor-car design, change rapidly, and whether the downdraught carburettor is merely a vagary of fashion or will definitely mark an advance remains to be seen". But this type of carburettor is still with us, and it would appear that it will remain so for some years to come; it is still universally used on American cars.

Carburettor icing

When premium fuels were re-introduced in the United States after World War II, there was an epidemic of carburettor icing, Fig. 2. In some instances, this was so serious that a vehicle would come to a standstill owing to starvation of air. When these premium fuels were re-introduced in Great Britain some two years later, a similar epidemic was encountered. Extensive investigations were carried out by the fuel companies, together with the carburettor and motor vehicle manufacturers. Anti-icing additives were introduced into premium fuels, and efforts were made also by both the carburettor and motor manufacturers to combat the trouble. All this proved so effective that for several years icing complaints were almost non-existent, at least so far as users of premium fuels were concerned. During the last winter, however, the trouble appears to have come into prominence again, and on makes of vehicle that have been trouble-free in this respect for some years. Whether this is due to some peculiarity of the fuel, such as increased volatility or alteration in the kind of anti-icing additives used, remains to be proved. It is interesting that, on the American Ford Falcon, the throttle body of the carburettor is water jacketed and thus heated by the engine coolant, Fig. 3.

The foregoing remarks refer to serious icing, which may cause the vehicle's speed to be reduced or may even bring it to a standstill as a result of obstruction of the main air

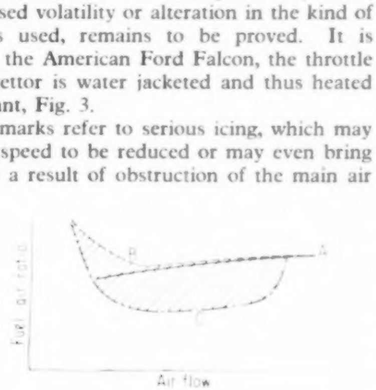
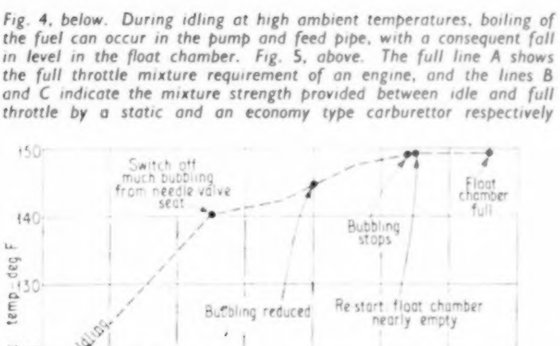


Fig. 4, below. During idling at high ambient temperatures, boiling of the fuel can occur in the pump and feed pipe, with a consequent fall in level in the float chamber. Fig. 5, above. The full line A shows the full throttle mixture requirement of an engine, and the lines B and C indicate the mixture strength provided between idle and full throttle by a static and an economy type carburettor respectively



passage. But in ordinary circumstances, before the recent epidemic, small amounts of accretion of ice on the throttle during warm-up from cold were inevitable. Apart from a slightly increased tendency to stall at traffic stops for the first mile or two during the warm-up period, this is a fairly mild inconvenience as compared with the complete stoppage due to venturi icing. The methods of combating these troubles are too numerous to be dealt with in this article[3].

Contrary to common belief, very cold weather does not generally cause carburettor icing. Humidity is the most important factor, and critical icing conditions occur in the ambient temperature band between 40 deg and 60 deg F, with the humidity in the region of 90 to 100 per cent[3].

Vapour lock

Another condition that must be catered for is that of vapour formation, and the resultant hot-starting complaints that accrue from it, Fig. 4. It occurs because, at high temperatures of operation, the lighter, low boiling-point fractions of the fuel form vapour in the system. Obviously, the fuel system installation in a vehicle must be laid out having regard to the possibility of vapour formation. The fuel line, fuel pump and carburettor should be protected as much as possible from radiated and conducted heat, by suitable routing and generous use of heat shields. This is particularly necessary if a crankcase-mounted mechanical fuel pump is employed.

In hot weather, a tremendous quantity of fuel vapour can be generated in the fuel pump and the pipe-line between the pump and the carburettor[5]. The only possible outlet for this vapour is through the needle valve of the carburettor, into the float chamber and out through the float chamber vent. In the most common layout, the float chamber is vented to atmosphere, and this seems the best compromise arrangement since, if the fuel vapour is ejected from the vent orifice out into the underbonnet compartment, it can do no damage. The alternative scheme is that in which, in an endeavour to maintain a constant pressure drop across the carburettor in the event of the air filter's becoming dirty, the float chamber is vented into the air intake: this can only accentuate hot-starting troubles. From the service aspect, should a customer complain of difficult hot-starting there is no easy remedy if internal venting is employed.

Requirements

At this stage it will be advantageous to list in brief detail the general requirements which a modern carburettor should fulfil, and then to examine in practical terms how these demands are met by the current range of Zenith carburettors. They are as follows:

Easy cold-starting and quick drive away
Good idling characteristics
Smooth progression from idling to the normal operating range
Economical operation at part throttle
Mixture enrichment for maximum power
Good acceleration.

For cold-starting, at temperatures down to 0 deg F and below, and to permit the car to be driven away after a few moments' warm-up, the carburettor should be capable of metering an extremely rich mixture, in the region of 1 : 1 of fuel and air by weight, under these conditions. The fast-idle speed should be controlled automatically in conjunction with the starting mixture device, not only so that the engine speed is sufficient for the cold start but also to prevent stalling when the vehicle is driven away from rest.

The idle system should provide a steady supply of metered fuel and air. It should also be capable of being easily adjusted to suit the demands of the individual engine.

Progression is the term used by the Zenith Carburetter

PART II

The second part of this article will be published in the July issue of ***Automobile Engineer.*** It will deal with the way in which the requirements outlined in this first part are met by Zenith carburettors. Incidentally, the company that produces these carburettors also has its Jubilee this year, but about this more will be written in conjunction with the second part of the article.

Co. Ltd. to describe the function of the small system employed to supply a metered quantity of mixture of the required strength over the early portion of the throttle opening. It is actually an extension of the idle range, that is, it is designed to cover the short range of throttle opening between the idle and the main metering conditions.

Although there is a number of small carburettors in use that have no part-throttle economy system, the majority of Zenith carburettors forming standard equipment of road vehicles are fitted with a mechanical automatic economy device. The essential difference betwen the economy type and the so-called static version is illustrated in Fig. 5, which is representative of the type of curve that might be obtained when mixture strength, in terms of fuel : air ratio by weight, is plotted against airflow. In this illustration, the thick black line represents an assumed mixture strength requirement, over the whole of the full-throttle range, with both types of carburettor. The dotted line is typical of the kind of mixture ratio curve likely to be obtained with a static carburettor. On the left is the highest point, representing the mixture strength when the engine is idling. Apart from during cold starting, and possibly when an acceleration pump is in operation, idling is the richest portion of the range. As the throttle is opened, the mixture strength weakens, and it continues to do so until the throttle is open to approximately the beginning of the cruising range. Here the curve flattens out until it is coincident with or slightly above the full-throttle requirement curve and remains so all the way up to the full-throttle condition. Thus, over the cruising range, the strength of the mixture is the same, or very slightly richer than that required for the full-throttle condition. On some engines, notably those having four cylinders or less, there are heavy induction pulsations that affect the carburettor : when the engine is operated at part throttle, these pulsations are damped down, with the result that the mixture is weakened a little, and thus a small degree of economy is automatically obtained. Let us now examine the chain dotted line. This represents the part-throttle, weak-mixture curve metered by an economy type carburettor. It will be observed that it comes down much lower than the dotted line of the static carburettor. Hence the gross fuel consumption over the cruising range will be less. The shaded portion within the envelope formed by the two part-throttle curves represents the fuel economy, as between the static and economy types of carburettor. In a subsequent section the method of determining the weakest mixture that an engine will accept will be dealt with, and the manner in which the Zenith carburettor metering system caters for these demands will be described.

With an economy system it is necessary to incorporate some means of enriching the mixture to obtain high power output at full throttle. With Zenith instruments, this increase in fuel flow occurs automatically when the throttle is opened to, or near to, the point at which maximum power is obtained. This is done either by means of an additional valve and jet, which meters extra fuel at full throttle, or by admitting a larger quantity of air into the emulsion system at part throttle, and reducing it at full throttle.

On Zenith carburettors the acceleration pump is of the piston type. It is linked with the throttle spindle, and the acceleration charge is metered through a small calibrated jet orifice each time the throttle is opened.

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2. C. H. FISHER: "Downdraught Carburation", *Automobile Engineer*, May 1953.
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Foamed Plastics

INFORMATION has been received from the Atlantic Research Corporation, Alexandria, Virginia, U.S.A., of a newly developed foamed plastics material known as ArcMold. It is available in rigid and flexible forms, and the ingredients are mixed where required, without any previous preparation. By varying the proportions in the mixture, a wide range of densities can be obtained, ranging from 1 lb/ft³ to 40 lb/ft³. Also, foaming can be arranged to begin within 15 sec of mixing, and to expand to the desired extent within 30 sec, or the reaction can be delayed appreciably to suit the particular conditions.

The method of mixing is not critical, and the foam will expand *in situ* to any shape. It is claimed to bond itself to any clean surface as it rises, but if separation is necessary heavy wax serves as a release agent. After the reaction is completed, the exposed surfaces of the foam are smooth and are not sticky.

Between −65 deg F and +212 deg F, ArcMold foams have better insulating properties than cork, and they can be produced in the open air under most atmospheric conditions. They are impervious to water and its vapour, and resist attack by fungus, bacteria and termites. In their rigid form, the foams have high strength : weight ratios. As an example, the 38 lb/ft³ foam has twice the compressive strength of concrete. Because of this strength and the ability to absorb impact energy, ArcMold foams have structural as well as insulating properties. Among the uses envisaged for the rigid form are lightweight panels for goods vehicle bodies and buildings, also thermal and acoustic insulating board. The flexible type could be used for vehicle seat cushions and for shock-absorbent packaging of delicate instruments or scientific equipment.

Front Wheel Drive

Examination of the Advantages and General Characteristics of the Front Wheel Drive Arrangement in Relation to the Basic Requirements for Car Layouts

G. LJUNGSTRÖM*

THE fundamental principles of front wheel drive are so well established that the author hopes to be excused if only a small bibliography is given. Also, since there are now no inherent mechanical difficulties in the layout of the f.w.d. car, the machinery design problems will not be treated. It must be added, too, that only cars with conventional forward facing seating, for at least four persons, and only four-wheel vehicles are considered. The essential requirements for passenger cars are given in the Table, and the aim of the designer should be at meeting these requirements under the following conditions.

In operation both at home and abroad
On firm surfaces as well as *on soft ground*
On level roads and *on steep gradients*
Not only *on open fast roads* but also *in narrow lanes and drives*
During summer as well as *in winter*
In daylight and in darkness
With either the driver *alone* or *with full load*
In calm as well as in windy weather.

Of these conditions, those that are printed in italics are the ones that are substantially influenced by the choice of traction, as also are those similarly printed in the Table. This paper will deal with f.w.d. in relation to these specific factors in the order listed below; in addition, the influence of varying loads and their effect on driving technique will be discussed.

Seating comfort, roominess, ride and well-being
Safety:
- at high speed
- at low speed
- when braking

Driving: .
- on slippery roads
- in strong winds.

Seating comfort, roominess, ride, and well-being

Illustrated diagrammatically in Fig. 1 is the course of evolution during the first three or four decades of motor-car construction. In general, we have now reached the stage at which it has been established, and accepted, that the passengers should be carried between the two axles and that the mechanical components should not intrude upon the space for the bodies and limbs of the occupants.

A low centre of gravity gives good ride characteristics in the following two ways: first, because the closer to the road surface are the occupants, the smaller are the side movements due to assymmetrically applied bumps; secondly, because a relatively low roll centre can be adopted without risk of undue heel-over when cornering. It follows that both the mechanical components and the passengers should be as low as possible.

The best conditions practicable are obtained if the floor is at a height equal to the minimum acceptable ground clearance, that is, no other obstructions should be lower. This also gives a maximum interior space obtainable for given external dimensions. A large interior space is beneficial in respect of ventilation, moisture control and general well-being. Both f.w.d. and rear wheel drive enable this condition to be obtained, provided the engine is placed together with the drive, so that there is no transmission tunnel to intrude above the floor level.

Practically all modern cars have independent front wheel suspension with wheel movements almost parallel in relation to the car, and it is generally accepted that there are good reasons for this. If f.w.d. transmission shafts are introduced, they do not complicate the front suspension system.

At the rear, the situation is different. Whereas f.w.d. gives the designer a free hand to employ a type of geometry suitable for obtaining the best ride, weight economy, road holding and space saving, rear-engined cars, invariably for reasons of simplicity, have a wheel movement geometry that gives undesirable tendencies under cornering conditions; and these tendencies are difficult to master by even the most ingenious design measures.

The space available between the front wheels is limited

Fig. 1. It required evolution over several decades for the most comfortable seating arrangement to be developed for the occupants of the car

by the suspension and steering linkages as well as the steering deflections of those wheels. In addition, the height of the front end is limited by requirements in respect of range of vision. Thus, there is substantially more space available for luggage at the rear than at the front, while the space at the front is, nevertheless, ample for all commonly employed types of engines; the actual layout of the transmission-engine unit can be varied to satisfy individual requirements of different installations. Good examples of layouts of f.w.d. cars are Dyna Panhard, Saab, DKW and B.M.C. ADO 15 model: Fig. 2 compares the relative merits, so far as space utilization is concerned, of different f.w.d. engine and transmission arrangements. From the foregoing discussion, the conclusions to be drawn are that the installation of the engine at the front, with f.w.d, is beneficial in respect of the following:

Space utilization
Efficiency of rear suspension geometry
Height of the centre of gravity
Comfort of the ride.

Safety at high speed

Although accidents may happen in or beside a stationary vehicle, the hazards undoubtedly increase with speed. It is an essential requirement, therefore, that the driver be readily able not only to steer the vehicle but also to regulate its speed, both when manoeuvring slowly in restricted spaces and at high speeds on open roads.

There are, of course, good reasons for steering with only the front wheels. A diagram is given, in Fig. 3, to show how, with a pair of front wheels free to turn about two independent vertical axes, both pairs will, owing to the reluctance of the tyres to change their angular attitude in relation to the road surface, align themselves in such a way that the motion of the vehicle tends towards a straight course. With steered

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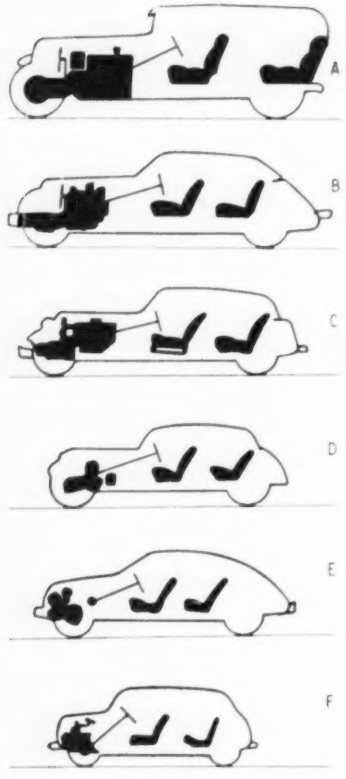


Fig. 2. Some different front wheel drive layouts that have been used during the last thirty years

A *Cord L29, 1929;*
B *Cord 810-812, 1936;*
C *Citroën, 1934;*
D *DKW, 1933;*
E *Saab 92, 1947;*
F *B.M.C. ADO 15, 1959.*

wheels at the rear end, on the other hand, the sharpness of the turn tends to be rapidly increased.

The inherent static self-centring discussed in the preceding paragraph is effective at all speeds, and at the higher speeds is assisted by the dynamic self-aligning torques, which have been dealt with in many technical papers on tyre characteristics. It follows, not surprisingly, that for safe and easy handling, the front wheels must be the steered wheels. This helps the driver to keep a straight course, to return the steering wheel to the neutral position after a bend, and gives the driver a feel of the amount of road friction available at any moment.

Of equal fundamental significance is directional stability at speed, that is, understeer. Nowadays even sports car manufacturers seek to give their cars understeer characteristics. However, many have failed to obtain understeer in all circumstances, particularly when carrying a full load. With normal saloon car seating arrangements, a vehicle that is only slightly tail-heavy with two occupants at the front may become undesirably so with all the seats occupied. On the other hand a nose-heavy car will become less so, and perhaps eventually slightly tail-heavy, as the load is increased; such variations are not difficult for the driver to master, and a clear understeer can be obtained. Typical figures for weight distribution are as follows:

For rear engined cars:

Two at the front:	43	per cent on front wheels
Five occupants:	40	,, ,, ,, ,, ,,

For f.w.d. cars:

Two at the front:	60	,, ,, ,, ,, ,,
Five occupants:	52	,, ,, ,, ,, ,,

Most of the arguments put forward regarding steering characteristics are strictly applicable only if several simplifying assumptions are accepted, and some of these are as follows. Normal tyres, of the same type, are employed on all four wheels; the road surface is smooth, hard and dry; and the tyre inflation pressure is unaltered as the load is varied—but it need not necessarily be the same pressure front and rear, the pressures being assumed to be those recommended for general conditions. In most circumstances, the performance predicted from theoretical considerations is obtained in practice, although adverse conditions such as patches of ice on the road may, of course, upset all simple rules.

When a vehicle is steered to follow a curved path, the weight transfer to the outer wheels reduces the cornering force for a given slip angle. Therefore a low centre of gravity is a useful factor in respect of safety. The relative heights of the front and rear roll centres are also important. In Fig. 4 are shown the results of tests with two f.w.d. cars, both with rigid rear axles. The two lower curves indicate unsatisfactory characteristics, caused by an excessively high roll centre at the rear end: since, in these circumstances, the car does not heel over during a sharp turn, the front wheels exhibit little camber change and the lateral weight transfer is small; thus too high a cornering force is maintained at the front in relation to that at the rear wheels, and the rear end tends to drift outward in the turn. This example indicates that good longitudinal distribution of the weight, unless accompanied by suitable design of a number of other influencing elements, does not give directional stability.

Altogether, the characteristics inherent in the nose-heavy, f.w.d. car make understeer easily obtainable. This is also the case with a conventional rear-drive car with its engine at the front. In addition, however, the f.w.d. car naturally has a light rear axle, and even more important, if prolonged wheel-spin occurs on a slippery surface, the vehicle will only straighten out, so the rear end will not break away. Of course, if control is to be maintained, one must not for more than a moment spin the wheels during cornering. An essential advantage of the f.w.d. vehicle is that, if the front wheels start to slide, control of the car can be regained just by easing up the throttle pedal—no hectic rotation of the steering wheel is required. From all these considerations it can be seen that safety at speed seems to be catered for.

However, difficulties may be experienced during the transient stage, while the side load is continuously changing, when the vehicle is entering or leaving a curve. In these circumstances, the car is first set in rotation, and then maintained on a circular course, and *vice versa*. The rear axle of the Saab car, Fig. 5, is designed to give a pronounced damping effect on roll movements. This is done by attaching the shock absorber at a point in front of the geometric axis of the wheels. Thus, as can be seen from the illustration, the vertical strokes of the shock absorbers are longer, actually about 30 per cent, for a pure roll movement of the rear axle than they are with an equally high symmetrical vertical movement of both wheels. This effect, of course, may be

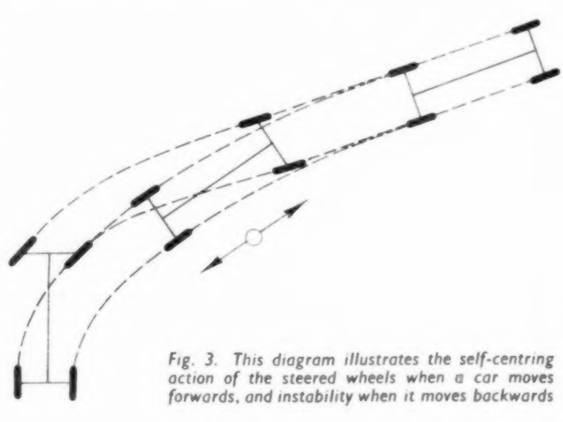


Fig. 3. This diagram illustrates the self-centring action of the steered wheels when a car moves forwards, and instability when it moves backwards

Table—ESSENTIAL BASIC REQUIREMENTS FOR PASSENGER CARS

Security	Well-being of Occupants	Economy
Against accidents:	Promoted by:	Promoted by:
at high speeds	*seating comfort*	*low weight*
at low speeds	*ample space*	small outside dimensions
when cornering	unobstructed visibility	low maintenance costs
when braking	suitable ventilation	low fuel consumption
if collisions occur	temperature control	*high cruising speed*
Against disturbances due to:	absence of violent movements,	
mechanical faults	that is, good suspension or ride	
hot weather		
cold weather		
rain, *snow*, *ice*		
In respect of health, influenced by:		
seating comfort		
ventilation		
ventilation control		
sound level		

obtained with some other rigid rear axle layouts, but scarcely with the swing axle. With orthodox rear axle and shock absorber layouts, the shock absorber stroke is often about 30 per cent shorter in roll movements than in twin wheel bump and rebound movements.

Safety at low speed

Traction is more often critical at low than at high speed. With f.w.d, and only one or two occupants, it is obviously extremely good on loose, horizontal surfaces; and, when full load is carried, it is not inferior to that of the normal front-engine, rear-drive car similarly laden. Also, if the driver is the sole occupant and the car is ascending gradients up to about 20 per cent, f.w.d. is, surprisingly, better than the ordinary front-heavy rear-drive car. With full load, all rear-drive cars have superior traction when ascending steep gradients, and the rear-engined car is of course excellent in these circumstances. Typical weight distribution values for different types of car on the level and when climbing gradients in the forward and reverse directions are given in Fig. 6.

Attention is drawn to the unfavourable performance of the conventional rigid axle with limited-slip differential and with its pinion reaction tending to lift one wheel. Under these conditions, a load reduction of about 40 lb on one rear wheel is not uncommon. On a climb curving to the right, this loss of load, and therefore of adhesion, in conjunction with the effect of the limited-slip differential, may cause the right-hand wheel to spin even on what would normally be a satisfactory surface; thus the driver may be deprived of about half his directional control of the rear end. So with this arrangement, what is gained in getaway is lost in directional control.

The fact that the driving wheels of a f.w.d. car travel a longer distance than those of a rear-driven car leads to more advantageous utilization of the available torque. With a car having, for example, a wheelbase of 100 in, a track of 50 in and a turning circle of 400 in, the front wheels, on full lock, travel a 20 per cent longer distance than the rear ones. This is true for both forward and reverse motions, and the good traction of a f.w.d. vehicle when reversing up a slope can be most useful.

Safety when braking

A f.w.d. car should be given a brake torque distribution which prevents the rear wheels locking before the front ones, even when only the driver is carried in the car. Then, for all other loads, the margin of safety against the rear wheels locking will be wider and, during excessively hard braking, the car will proceed straight ahead, enabling the driver to brake hard so long as no turn is required. The moment the braking is sufficiently reduced, immediate directional control is regained without any need for skilled handling of the steering wheel. In this connection, it is of interest that the British Road Research Laboratory has found that, of all the accidents caused by loss of control, break-away of the rear wheels is the largest clearly observed group.

Admittedly, if the distribution of the braking effort of a f.w.d. car is such that the rear wheels will not lock when only the driver is carried, these wheels will not be fully utilized for braking, and thus the maximum physically possible retardation is not available. A tail-heavy car may have perhaps 50 : 50 brake torque distribution between the front and rear wheels, which of course could be ideal as regards maximum retardation alone. The effective difference between tail-heavy and nose-heavy cars is, however, moderate owing to the fact that the inflation pressure is normally some 10 per cent higher for the front wheels in the f.w.d. car and *vice versa*

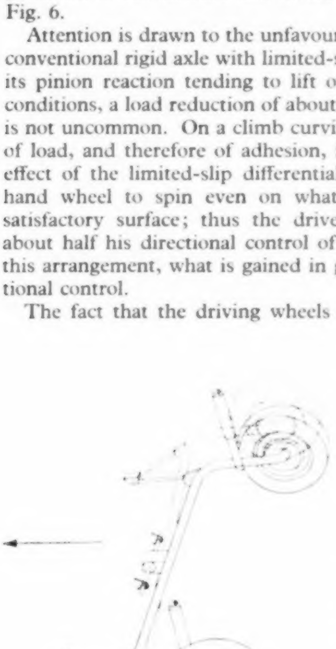
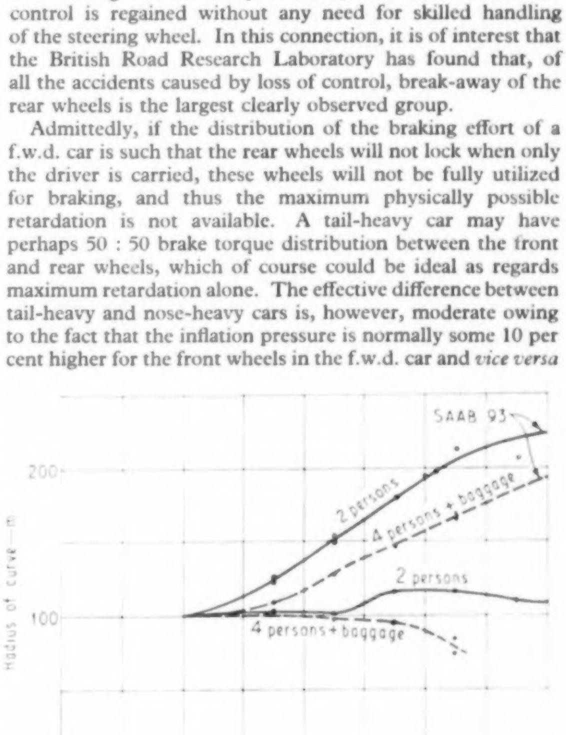


Fig. 4, right: Test results obtained with the steering wheel set at a constant angle. The upper two curves are those for a car that has understeer characteristics, while the lower two are for a car that exhibits an amount of oversteer that increases with speed, especially when it is heavily laden

Fig. 5, left: This type of rear axle gives ample clearance for the fuel tank; good utilization of space in the body; freedom of choice of roll centre location, with a central rubber bearing; and low unsprung weight



for the rear-engined car. Thus, each type of car utilizes its wheels to a nearly equal degree in relation to the vertical load carrying capacity of their tyres, as inflated.

The author takes the liberty here to introduce the expression and conception *steadfast understeer*, which is applicable only to a car that never tends to travel in a sharper curve than that on which the driver steers it, and always moderates the path if the driver turns the wheel too sharply, or accelerates or brakes too hard. It may be correctly argued that such features do not give optimum manoeuvrability, but if the possibility of human errors of judgement is taken into account, it is not surprising that experience indicates that one feels at ease when driving such a car. With f.w.d. it is necessary to accept only one inherent defect with regard to handling characteristics: that is, the possibility of the floating out of the front end if the adhesion is over estimated by the driver.

A warning is justified in this connection. No car, however well devised, can accelerate, brake or turn harder than the instantaneous road-tyre friction permits. A safety margin should always be kept in hand. The driver must, by careful training, learn to feel the character of each kind of surface and each tendency of the car; no car can justly be called fool-proof. So far as the designer is concerned, the basic requirement that he should take into consideration is that the handling characteristics of the vehicle must remain constant irrespective of the load carried.

Aids towards better handling are gradually being introduced. Modern tyres give a cornering power that is higher than hitherto and which varies less with inflation pressure—a rear wheel puncture, however, is still a potential danger. Brake load distribution can be modified by simple additional valves so that, when the retardation increases, less braking is applied to the rear wheels. The B.M.C. ADO 15 model, for example, has a pressure-sensitive valve for a similar purpose.

Driving on slippery roads

It is useful, and educating, when driving alone on icy roads, periodically to spin the front wheels purposely, and at the same time to swing the steering wheel to and fro. In this way, one can prove three facts: first, that front-wheel spin does not mean loss of directional stability; secondly, that the road is actually slippery; thirdly, one is reminded that the car will not respond if the steering wheel is turned while too much throttle is applied.

Fig. 6. Typical weight distribution values for different types of car on the level and when climbing gradients in the forward and reverse directions. The top three in each row are those with the driver and one passenger, while the lower one is with all of the seats occupied

A *front wheel drive;* **B** *orthodox rear wheel drive with engine at the front,* **C** *rear engine, rear wheel drive*

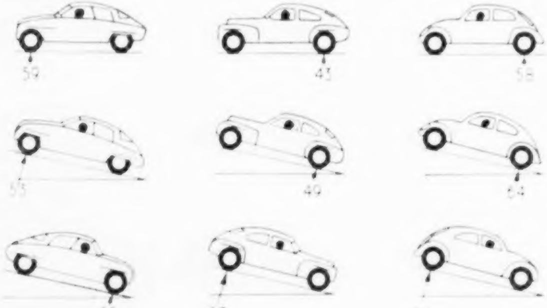


Fig. 7. At full lock, the steered wheels travel a distance that is 20 per cent longer than that traversed by the fixed wheels; therefore, if the front wheels are driven, the traction required is only 84 per cent of that which would be needed to drive the rear wheels of the vehicle

The rule, from the days when only rear wheels had brakes, that braking on ice must not be attempted and that braking should be done by means of the engine alone, no longer applies: well designed and correctly functioning four-wheel brakes give more than twice the retardation and less risk of loss of control. In Scandinavia, many experienced drivers even recommend declutching, with the object of obtaining a maximum of directional control between the spells of braking. This complicated sequence of operations can be avoided, with the same result, if a free wheel is incorporated. The driver then needs to operate only two controls for avoiding a potential accident: they are the steering wheel and the brake pedal.

Improved traction and steerability can be obtained by using snow tyres, or tyres with steel studs or chains. If snow tyres or studded tyres are used, it is preferable for all four wheels to be similarly fitted. Improved cornering power of only the front wheels gives directional instability. On icy roads, the improved effective traction on full steering lock, mentioned in the section under the heading "Safety at low speed", may sometimes come in useful for climbing a gradient zig-zag fashion.

Driving in strong winds

Any elongated, bluntly shaped object tends to yaw if moved fast through the air, the resultant effective centre of aerodynamic load always being located ahead of the centre of volume of the object. Cars with rounded ends, when driven in a side wind, will be swung to leeward unless they have tail fins. These latter devices improve control and make driving easier. They can be relatively small, while still being fully effective, for cars with more weight on their front wheels than on their rear ones, and the total side load on the vehicle will be slightly less than in the case of an adequately finned tail-heavy car.

Conclusions

If f.w.d. is employed in suitable combination with other elements, the result is a motor-car equal or superior to other types in respect of the following essential characteristics: comfort, weight economy, space economy, directional stability and handling under all conditions. Indeed, the only significant disadvantage seems to be the inferior traction in climbing very steep gradients with a full load. Although this is admittedly an important case, it is far from being a decisive one.

It is the sincere belief of the author that too much traditional thinking is one reason why f.w.d. is not more widely used. Another is the hectic race for increased production, which continuously discourages the large motor-car manu-

facturers from taking the tremendous financial risks involved with a new type of product.

There was at one time a similar situation in the aircraft industry. In 1945, few aeroplanes were equipped with nose wheels, although it was known that those of the conventional layout, with tail wheels, tended to ground-loop when rolling-on after landing. Once the first manufacturer had set the example, though, almost all of the remainder adopted the new principle. Incidentally, it is not uncommon for cars of today to show, under unfavourable conditions, a tendency to make ground loops.

Although in no way pioneers, the Saab Aircraft Co. Motor Car division has had more than ten years experience in designing, building and driving f.w.d. cars, and the author is indebted to the Company for permission to draw on that experience and to publish this paper on the overall aspects.

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TESTING LUBRICATING OILS

Closely Controlled Temperatures in Tests on Engines and Transmissions Under Simulated Working Conditions at the BP Research Centre, Sunbury-on-Thames

EVERY advance in the design or development of engines or transmission units is likely to lead to more stringent specifications of the lubricating oils required to maintain optimum working conditions. These may, in fact, necessitate the production of new blends, new treatments, or new additives to withstand higher loading pressures, higher operating temperatures, higher or lower viscosity, or other exacting requirements. In order to keep abreast with such developments or, indeed, to be somewhat in advance of demands if possible, the oil industry devotes continually a considerable research effort, including full-scale and long-term investigations. In some instances, progress in oil technology has made possible the practical development and wide application of major advances in component design—the advent of hypoid gear lubricants being a case in point.

At the Research Centre of the British Petroleum Co. Ltd., at Sunbury-on-Thames, investigation is conducted in every aspect of oil development. A most interesting part of the work, since it deals with end products, is carried on in the Applications Research Section, where great ingenuity is employed in the simulation of severe but typical working conditions under which oils and additives are used. An illustration, Fig. 1, shows part of a test room in this section in which transmission oil tests are undertaken. The set-up shown is concerned with the development of lubricants for hypoid rear axles and the test axle, at the right, is driven by a converted Austin Princess petrol engine at the extreme left. At each end of the axle is a large, heavy flywheel calculated to represent the inertia of a motor vehicle during acceleration tests. In the middle distance is a variable water brake, which for acceleration tests can be arranged to be representative of wind resistance, while rolling resistance is simulated by the total friction in the mechanism. All the relevant conditions encountered by a vehicle in road use

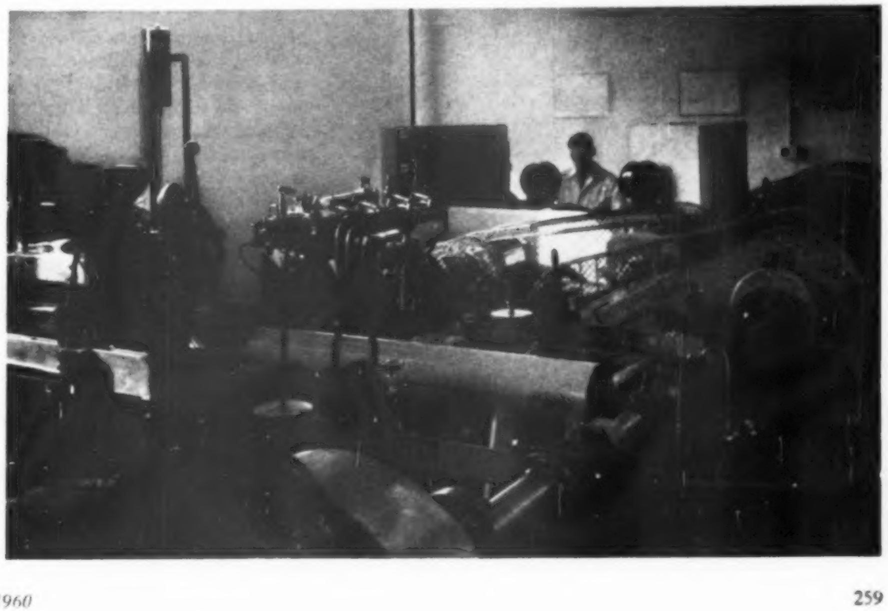

Fig. 1. Rig for hypoid gear lubricant tests at the BP Research Centre at Sunbury. Heavy fly-wheels simulate vehicle inertia, a variable water brake the wind resistance, and internal friction the rolling resistance

may be simulated on this rig with a high degree of accuracy.

When running tests of this character there is a need to keep temperatures constant within much closer limits than are maintained in normal operation. This is effected by an electronic control system, which is applied first of all to the engine cooling water. By regulating the rate of heat removal through the coolant, the whole engine is kept at a reasonably constant temperature, which makes it easier to maintain the oil temperature itself within fine limits.

The need for high standards of accuracy and reliability over long periods of operation is complicated by the fact that vibration in the test room is usually severe. To meet these requirements, the control equipment shown in Fig. 2 was eventually selected, comprising two Type N 241 temperature control units by Airmec Ltd., of High Wycombe, Bucks. The upper instrument controls the oil temperature, the lower instrument that of the cooling water. Each controller employs a bridge circuit, one arm of which is a temperature-sensitive platinum element inserted in the controlled medium. Unbalance in the circuit due to temperature changes is amplified in a single-valve amplifier and used to operate a relay that can carry out any type of on-off control function. The instrument operates over the wide range from −80 deg C to +500 deg C in four steps, fine control of the desired value being made by movement of the central knob which carries a scale calibrated in arbitrary units.

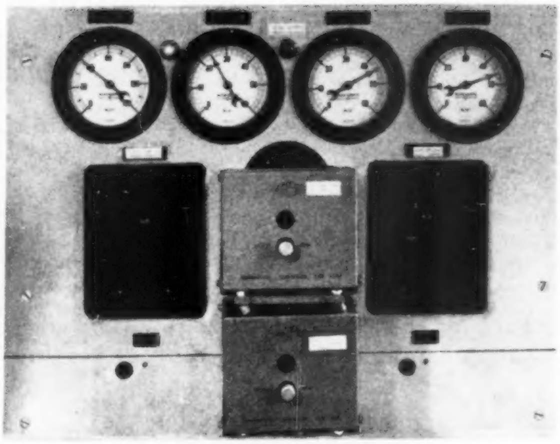

Fig. 2. Airmec control units adjust and maintain engine coolant and oil temperatures within close limits. The controllers operate on the bridge principle, unbalance being amplified and used to control heat exchange systems on the test rig

In this application, the relay is used to operate solenoid valves in association with heat-exchanger circuits in the oil and water lines. The control gear for the cooling water is shown in Fig. 3, with the sensing element inserted in the cylinder-head take-off, at the top right. Operating on a closed circuit, the engine cooling water passes through the vertical cylindrical heat-exchanger at the left. In this unit, heat is given up to a secondary water supply which enters through the valves at the left and passes out, on a total-loss basis, into the funnelled conduit in the foreground and thence to a cooling tank for eventual re-use.

Fig. 3. Engine coolant is circulated through a heat exchanger. The solenoid valve is operated by the controller to vary the by-pass ratio in the secondary water flow. Oil temperature is similarly controlled

The large hand-valve at the left provides a total by-pass for the secondary water, to give a rapid warm-up when the engine is started from cold. This valve is then adjusted coarsely to establish approximate equilibrium when the test rig is running at full load. A secondary by-pass circuit around this valve is provided with a solenoid-operated valve which is controlled by the Airmec unit. The controller thus has to provide fine control of small variations only in conditions on either side of the manually set value. It is found that in this way control can be maintained, under all working conditions, within about 2½ deg C. This must be considered a very good figure, in view of the simple on-off type control used in conjunction with a fairly large through-put, the considerable lag due to the heat capacity of the system, and the fact that control is imposed on the secondary circuit only.

Lubricating oil temperature is controlled in a similar manner. The sump base has been modified to provide a take-off for the oil, which is passed by an auxiliary pump through a small heat-exchanger, just discernible at the the extreme bottom right of Fig. 3, and returned to the sump. A second solenoid valve controls the flow of secondary water through this exchanger, exactly as in the engine coolant system. Oil and water temperatures are each held at a nominal temperature of 80 deg C.

When the engine is used merely as the prime mover in a transmission test, as in Fig. 1, such strict control of the engine oil temperature is not essential. However, the automatic control system is used, since such tests must be run continuously. During the night shift, one operator may be responsible for the supervision of a variety of equipment and thus be unable to give undivided attention. Automatic control of temperatures ensures that there is no danger of overheating, and possibly fire, as a result of oil supply failure. In the event of runaway, the engine is automatically shut down. The same fail-safe operation is provided automatically in the event of failure of any of the supplies to the control circuit.

This simple, but none the less accurate and reliable, control system is used widely in British Petroleum research laboratories, on many different types of work demanding close control of temperature. The continually changing nature of the work in progress takes full advantage of its adaptability to virtually any form of control action, in some cases by direct or relay switching of heating elements, in others by solenoid operation of valve-controlled heating or cooling circuits in functional tests or processing operations.

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Brake Geometry

Theory of Internal Expanding Rigid Types

W. STEEDS, O.B.E., A.C.G.I., B.Sc.(Eng.), M.I.Mech.E.

INTERNAL expanding brakes used on motor vehicles are divisible into two distinct groups: they are (a) those in which the shoe has only one degree of freedom, and (b) those in which the shoe has two degrees of freedom. The first group is typified by the brakes shown in Fig. 1 (a) and (b), in which the shoes are pivoted on a fixed pin or pins; the degree of freedom then possessed by the shoe is one of rotation about the pivot. In the second group are the brakes in which the shoes merely bear on a fixed abutment, as indicated in Fig. 2 (a), and the brakes in which the shoe is pivoted to a link which itself is carried on a fixed pivot as in Fig. 2 (b). The degrees of freedom possessed by the brake shoe in Fig 2 (a) may be expressed as a freedom to roll without slip on the face of the abutment and freedom to move with a motion of translation parallel to the face xx of the abutment.

Since the movements of the shoe are very small and the heel of the shoe is usually a circular arc, the freedoms can also be expressed as freedom to rotate about the centre of curvature Q of the heel and, as before, freedom of translation parallel to the abutment. In the brake shown in Fig. 2 (b) the degrees of freedom may be expressed as freedom to rotate about the pivot pin Q and freedom to rotate about the pivot S. Again, since the motions are very small, the freedoms may be expressed as freedom of rotation about the point Q and freedom of translation perpendicular to SQ. It is thus seen that the brakes shown in Figs. 2 (a) and (b) are identical in so far as the degrees of freedom possessed by the shoes are concerned.

In this article, an analytical method of determining the forces acting on the brake shoe and the brake torque exerted on the brake drum is developed for brakes of the type shown in Fig. 2. It is then shown that the resulting expressions can be applied to the brakes of Fig. 1, by giving appropriate values to certain of the parameters involved in the expressions. It is the author's belief that this analysis has not previously been made or, at least, has not hitherto been published.

The analysis is based on the same assumptions that are usually made in the analysis of the conventional pivoted shoe brake. These are:

(1) The brake shoe is rigid
(2) The material of the shoe lining obeys Hooke's law
(3) The linings are of uniform thickness
(4) The linings are initially bedded-in, so that at the instant when the brakes are applied, contact occurs along the whole arc of the lining.

Refer now to Fig. 3: application of an actuating force $\boldsymbol{W}$ to the brake shoe shown therein will give the shoe a displacement which is composed of two components, namely a rotation through some angle θ about the centre Q and a translation of magnitude a parallel to the abutment xx. Consider any point A on the lining: the displacement of the shoe will produce a movement composed of $AB = \theta(QA)$, due to the rotation about Q, and of $BC = a$, due to the translation. When the brake drum is in position, the radial component AD of this movement is suppressed. The pressure p on the lining at the point A is then proportional to AD and may be taken as $k \times AD$ where k is a constant.

Now,
$$\begin{aligned} AD &= AB\cos\beta + BC\cos(\phi-\alpha) \\ &= \theta . QA\cos\beta + a(\cos\phi\cos\alpha + \sin\phi\sin\alpha) \\ &= \theta . M\sin\phi + a\sin\alpha\sin\phi + a\cos\alpha\cos\phi \end{aligned}$$

Hence,
$$p = k_1\sin\phi + k_2\cos\phi$$
$$\left.\begin{aligned} \text{where } k_1 &= k(M\theta + a\sin\alpha) \\ \text{and } k_2 &= k\,a\cos\alpha \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (1)$$

The radial force acting on an element of lining at A, which subtends an angle $d\phi$, is then $bpRd\phi$ where b is the width of the lining perpendicular to the plane of the diagram. It is, however, convenient to take b equal to unity, as this keeps it out of the expressions, and it can be restored in the final results if desired.

The moment of this force about S is then:

$$\begin{aligned} pRd\phi(SF) &= pRG\sin(\psi+\phi)\,d\phi \\ &= RG(k_1\sin\phi + k_2\cos\phi)\sin(\psi+\phi)\,d\phi \\ &= RG\,k_1\left(\frac{\sin 2\phi}{2}\sin\psi + \sin^2\phi\cos\psi\right)d\phi \\ &\quad + RG\,k_2\left(\frac{\sin 2\phi}{2}\cos\psi + \cos^2\phi\sin\psi\right)d\phi \end{aligned}$$

The frictional force on the element due to rotation of the drum is $\mu pRd\phi$, and its moment about S is:

$$\begin{aligned} \mu pR(FA)\,d\phi &= \mu pR\{R - G\cos(\psi+\phi)\}\,d\phi \\ &= \mu R^2(k_1\sin\phi + k_2\cos\phi)\,d\phi \\ &\quad - \mu RG(k_1\sin\phi + k_2\cos\phi)\cos(\psi+\phi)\,d\phi \\ &= \mu R^2(k_1\sin\phi + k_2\cos\phi)\,d\phi - \mu RG\,k_1\cos\psi\frac{\sin 2\phi}{2}d\phi \\ &\quad + \mu RG\,k_1\sin\psi\sin^2\phi\,d\phi - \mu RG\,k_2\cos\psi\cos^2\phi\,d\phi \\ &\quad + \mu RG\,k_2\sin\psi\frac{\sin 2\phi}{2}\,d\phi \end{aligned}$$

Taking moments about S therefore gives:

$$\begin{aligned} WL = \int_{\phi_1}^{\phi_2} \Bigg[& RGk_1\left(\sin\psi\frac{\sin 2\phi}{2} + \cos\psi\sin^2\phi\right) \\ & + RGk_2\left(\cos\psi\frac{\sin 2\phi}{2} + \sin\psi\cos^2\phi\right) \\ & - \mu R^2k_1\sin\phi - \mu R^2k_2\cos\phi + \mu RGk_1\cos\psi\frac{\sin 2\phi}{2} \\ & - \mu RGk_1\sin\psi\sin^2\phi + \mu RGk_2\cos\psi\cos^2\phi \\ & - \mu RGk_2\sin\psi\frac{\sin 2\phi}{2} \Bigg] d\phi \end{aligned}$$

where the two limits, ϕ_1 and ϕ_2, of the integration are the angles defining the positions of the ends of the lining.

Fig. 1. Diagram illustrating typical one degree of freedom systems

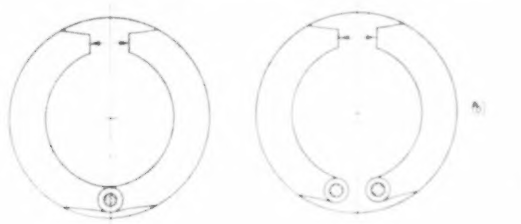
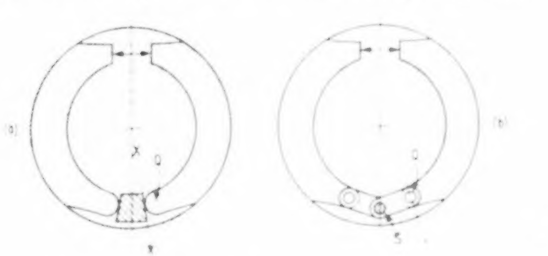


Fig. 2. The brakes represented below each have two degrees of freedom



Performing the integration gives the following equation:

$$\frac{WL}{R}=\Bigg[Gk_1\left\{-\sin\psi\frac{\cos 2\phi}{4}+\cos\psi\left(\frac{\phi}{2}-\frac{\sin 2\phi}{4}\right)\right\}$$
$$+Gk_2\left\{-\cos\psi\frac{\cos 2\phi}{4}+\sin\psi\left(\frac{\phi}{2}+\frac{\sin 2\phi}{4}\right)\right\}$$
$$+\mu Rk_1\cos\phi-\mu Rk_2\sin\phi-\mu Gk_1\cos\psi\frac{\cos 2\phi}{4}$$
$$-\mu Gk_1\sin\psi\left(\frac{\phi}{2}-\frac{\sin 2\phi}{4}\right)+\mu Gk_2\cos\psi\left(\frac{\phi}{2}+\frac{\sin 2\phi}{4}\right)$$
$$+\mu Gk_2\sin\psi\frac{\cos 2\phi}{4}\Bigg]_{\phi_1}^{\phi_2}$$

Re-arranged, this becomes,

$$\frac{WL}{R}=k_1\Bigg[G\left\{-\sin\psi\frac{\cos 2\phi}{4}+\cos\psi\left(\frac{\phi}{2}-\frac{\sin 2\phi}{4}\right)\right\}+\mu R\cos\phi$$
$$-\mu G\left\{\cos\psi\frac{\cos 2\phi}{4}+\sin\psi\left(\frac{\phi}{2}-\frac{\sin 2\phi}{4}\right)\right\}\Bigg]_{\phi_1}^{\phi_2}$$
$$+k_2\Bigg[G\left\{-\cos\psi\frac{\cos 2\phi}{4}+\sin\psi\left(\frac{\phi}{2}+\frac{\sin 2\phi}{4}\right)\right\}-\mu R\sin\phi$$
$$+\mu G\left\{\cos\psi\left(\frac{\phi}{2}+\frac{\sin 2\phi}{4}\right)+\sin\psi\frac{\cos 2\phi}{4}\right\}\Bigg]_{\phi_1}^{\phi_2}$$

$$\text{or } \frac{WL}{R}=k_1A+k_2B \qquad \ldots\ldots(2)$$

where A and B are the quantities inside the square brackets.

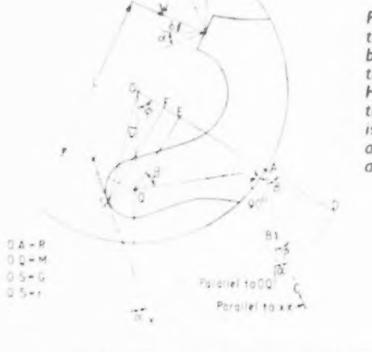


Fig. 3. Diagram showing the forces and reactions, based on the assumptions that the shoe is rigid, Hooke's law applies to the lining material, which is of uniform thickness, and that contact occurs along the whole lining arc

In equation (2) there is one equation for the determination of the constants k_1 and k_2. A second equation can be obtained on either of two assumptions relating to two physical conditions in the brake. The first of these assumptions is that there is no friction at the abutment, so that the shoe is perfectly free to slide on the abutment. It then follows that, for the shoe to be in equilibrium, the forces resolved parallel to the abutment must balance. This gives:

$$W\sin(\alpha+\delta)=\int_{\phi_1}^{\phi_2}\Big[(k_1\sin\phi+k_2\cos\phi)R\cos(\phi-\alpha)$$
$$-\mu(k_1\sin\phi+k_2\cos\phi)R\sin(\phi-\alpha)\Big]d\phi$$
$$=R\int_{\phi_1}^{\phi_2}\Big[(k_1\sin\phi+k_2\cos\phi)(\cos\phi\cos\alpha+\sin\phi\sin\alpha)$$
$$-\mu(k_1\sin\phi+k_2\cos\phi)(\sin\phi\cos\alpha-\cos\phi\sin\alpha)\Big]d\phi$$
$$\frac{W\sin(\alpha+\delta)}{R}=k_1\Big[-(\cos\alpha+\mu\sin\alpha)\frac{\cos 2\phi}{4}$$
$$+(\sin\alpha-\mu\cos\alpha)\left(\frac{\phi}{2}-\frac{\sin 2\phi}{4}\right)\Big]_{\phi_1}^{\phi_2}$$
$$+k_2\Big[-(\sin\alpha-\mu\cos\alpha)\frac{\cos 2\phi}{4}+(\cos\alpha+\mu\sin\alpha)\left(\frac{\phi}{2}+\frac{\sin 2\phi}{4}\right)\Big]_{\phi_1}^{\phi_2}$$
$$=k_1C+k_2D \qquad \ldots\ldots(3)$$

where C and D are the quantities in the square brackets.

There are now the two equations (2) and (3) from which to obtain the values of the constants k_1 and k_2. Solving for these:

$$k_1=\frac{WLD-WB\sin(\alpha+\delta)}{AD-BC}$$
$$\text{and}\quad k_2=\frac{WLC-WA\sin(\alpha+\delta)}{BC-DA}$$

The brake torque is now:

$$T=\int_{\phi_1}^{\phi_2}\mu pR^2d\phi=\int_{\phi_1}^{\phi_2}\mu(k_1\sin\phi+k_2\cos\phi)R^2d\phi$$
$$=\mu R^2[k_1(\cos\phi_1-\cos\phi_2)+k_2(\sin\phi_2-\sin\phi_1)] \qquad \ldots\ldots(4)$$

The second assumption that can be made in order to obtain a second equation for the constants k_1 and k_2 is that the friction at the abutment is sufficient to prevent any sliding, so that the shoe can only roll without slip on the abutment. In this case, the displacement a of the point Q is related to the rotation θ by the expression $a=r\theta$, and from equation (1):

$$\frac{k_1}{k_2}=\frac{M+r\sin\alpha}{r\cos\alpha} \qquad \ldots\ldots(5)$$

Using this in conjunction with equation (2) gives:

$$\frac{WL}{R}=k_1A+k_1\left(\frac{r\cos\alpha}{M+r\sin\alpha}\right)B$$
$$\therefore k_1=\frac{WL(M+r\sin\alpha)}{R[A(M+r\sin\alpha)+Br\cos\alpha]} \qquad \ldots\ldots(6)$$

Next, equation (5) gives k_2.

Then, the brake torque is given by equation (4) with these values of k_1 and k_2 inserted.

The second assumption is probably the more reasonable one when the brake shoe merely bears on the abutment, but the first assumption will apply if a roller or other means is provided to enable the shoe to move along the abutment easily; it will also apply to the type of brake shown in Fig. 2 (b).

This analysis has been done for a leading shoe, but that for a trailing shoe will differ only in that, all the way through, the terms involving μ will have their signs changed.

The expression for the brake torque developed by a pivoted shoe, such as is shown in Fig. 1, can now be obtained by using the second assumption made above and putting $r=0$. If this is done, then $a=r\theta=0$, ψ becomes zero and G becomes equal to M. Also, from equation (5), $k_2=0$. Putting these values in equation (2):

$$\frac{WL}{R}=k_1A=k_1\left[M\left(\frac{\phi}{2}-\frac{\sin 2\phi}{4}\right)+\mu R\cos\phi-\mu M\frac{\cos 2\phi}{4}\right]_{\phi_1}^{\phi_2}$$

which gives the value of k_1.

By inserting this value of k_1 in equation (4) and remembering that $k_2=0$, the following is obtained:

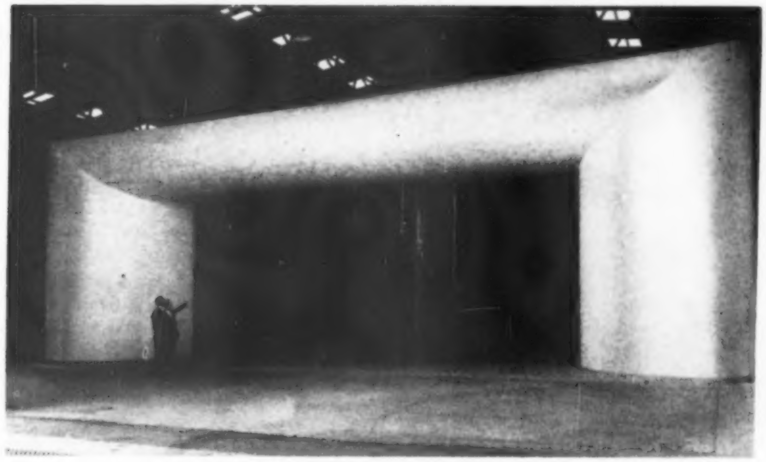
$$T=\frac{4\mu RWL}{M\left[\begin{array}{l}2(\phi_2-\phi_1)-\sin 2\phi_2+\sin 2\phi_1\\ \quad-\mu(\cos 2\phi_2-\cos 2\phi_1)+4\mu R(\cos\phi_2-\cos\phi_1)\end{array}\right]}$$

This is the expression that has been obtained, for the conventional rigid shoe pivoted on a fixed pivot, by several previous writers. It will, perhaps, be more easily recognised in the form it assumes for a symmetrical shoe—one in which $\phi_2=\pi-\phi_1$.

This is:

$$T=\frac{4\mu RWL}{M[2\pi-4\phi_1+2\sin 2\phi_1]-8\mu R\cos\phi_1}$$

M.I.R.A. Wind Tunnels



The impressive entry of the large wind tunnel at Lindley. Sheet steel is employed for the honeycomb matrix that straightens the air stream; vehicles can enter through the sliding middle portion

Full-Size and Quarter-Scale Tunnels, With a Chassis Dynamometer Embodied in the Larger One, Being Built at Lindley for the Study of Aerodynamic Problems

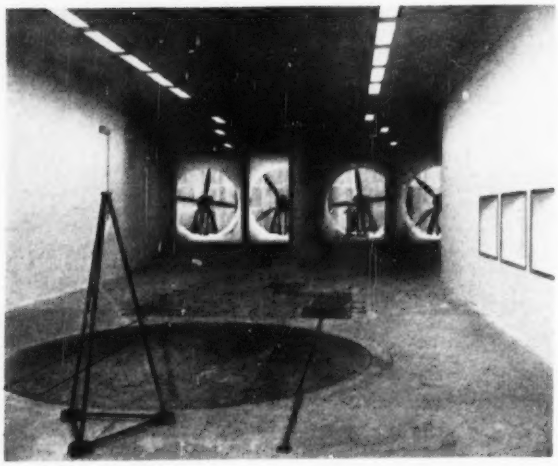
IN view of the increasing importance of the aerodynamic aspects of motor vehicle technology, it is significant that wind tunnel facilities should be in the process of installation at the Motor Industry Research Association's headquarters at Lindley, near Nuneaton, Warwickshire. The project covers two tunnels, one of which is large enough for the testing of actual vehicles, while the other is intended for quarter-scale models. In addition to its aerodynamic equipment, the larger of the two embodies a chassis dynamometer. This tunnel, which is designed for a maximum air speed of 80 m.p.h, is now nearing completion, and it is expected to be running during the M.I.R.A. Members' Day, June 15th. The smaller tunnel is designed for a maximum air speed of 90 m.p.h; constructional work on it has not yet begun, but some of the apparatus has already been delivered to the Association.

Both tunnels were designed entirely by the Association's staff, though assistance on some points was given by the National Physical Laboratory of the D.S.I.R., at Teddington. The site is a disused aircraft hangar—a relic of the time when the Lindley proving ground was an airfield. Since economic considerations precluded the use of a recirculating air system, the enclosure of the tunnels within a building was considered essential, to avoid disturbing atmospheric conditions such as gusty winds, heavy rain or snow. It also permitted the employment of a simpler and cheaper structure, in that weatherproof cladding was not necessary.

To verify the practicability of proposed layouts of the full-size tunnel, several working scale models were made in the early design stages; one of these models was, in fact, displayed on the M.I.R.A. stand at the London Motor Show last October, at which time the building of the tunnel had just started. The material used for most of the structure is timber, and an idea of the construction can be gained from one of the accompanying illustrations. It is noteworthy that all wood, both inside and out, is coated with fire-retardant paint. The overall length of the tunnel is 150 ft, and it is divided into entry, straightening, contraction, working, and diffuser sections. A rectangular cross-section is employed, with corner fillets between the side walls and ceiling, because the front elevation of most vehicles, when yawed, approximates to a rectangle.

To give the optimum flow characteristics to the entry of the tunnel, the top and side walls are given an initial lead-in of large compound radius. Mounted in the actual opening, which is 37 ft 8 in wide × 14 ft 6 in high, are the straightening vanes: these take the form of a square-cell honeycomb, 3 ft deep and fabricated in sections from sheet steel. The squares have 11·67 in sides, inclined at 45 deg to the horizontal: this diagonal arrangement of the vanes was preferred to a vertical and horizontal disposition because of the greater rigidity conferred by the resultant triangulation of the frame containing the honeycomb sections. One of the two entrances for vehicles is provided by moving the middle third of the honeycomb sideways. For this purpose, the unit is positioned just ahead of the flanking sections and is mounted on rollers running in guide channels sunk into the floor.

Immediately downstream of the straightening vanes is a short parallel portion of the tunnel. Adjacent to it is the contraction section, 28 ft in length, in which the width of the tunnel is reduced to 26 ft by a reflex curve in each side wall; the height remains constant. The contraction section blends directly into the working section, which is 26 ft wide and 14 ft 6 in high throughout its length of 50 ft. Below the floor is a pit containing the aerodynamic balance unit and the chassis dynamometer, both of which will be described later. The circular platform of the balance, which is flush with the floor, is sited virtually midway between the ends of the working section, whereas the rollers of the dynamometer are to the rear of it. This relative positioning would appear to be the best compromise, though a front-



On a stand ahead of the aerodynamic balance platform can be seen a pitot-static unit used for calibration; beyond the platform are the rollers of the chassis dynamometer. Other features of interest are the flush lighting and the walls that divide the air flow to the fans

drive vehicle on the dynamometer might perhaps be nearer the tail end of the section than is desirable in terms of the air flow.

Beyond the working section, the tunnel sides are blended by a radius into the diffuser, the angle of divergence of which is constant at 13 deg, as measured between the boundary walls. At the rear of the diffuser are four fans, each of which is mounted with its axis horizontal and runs with a small radial clearance in its own duct. An approximately equal distribution of the air flow among the fans is ensured by a double division of the main air stream. Projecting well into the diffuser from the rear of the tunnel is a medial vertical wall, which has a capping of part-aerofoil section on its leading edge. It divides the air stream into two, directing each portion towards one pair of fans. The flow is then sub-divided into four by two shorter vertical walls, one between the fans of each pair; from the leading edges of these two walls to the planes of rotation of the fans, the cross-section of each duct changes from rectangular to circular. In the plan view, each of the planes of rotation forms a chord of an arc struck from the middle of the diffuser, and the layout is symmetrical about the longitudinal axis of the tunnel — an arrangement that contributes to a homogeneous air flow.

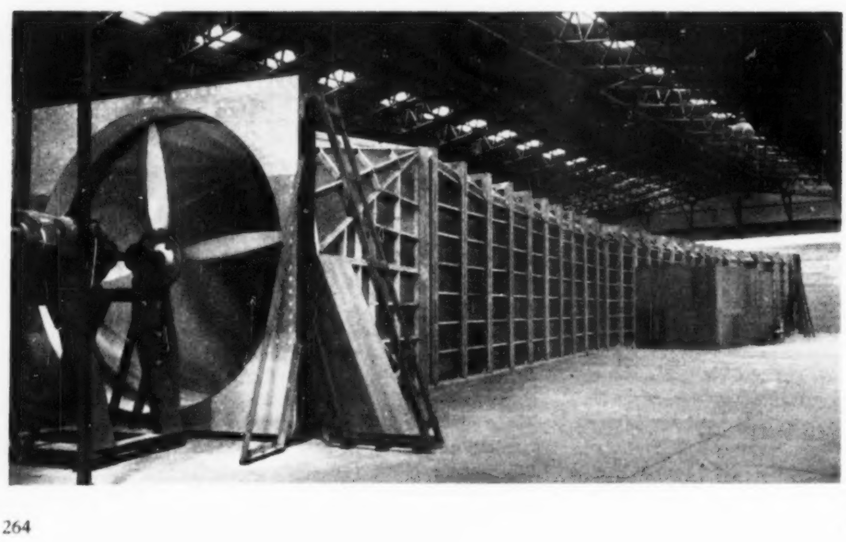
The use of four fans instead of the normal one was dictated partly by the rectangular cross section of the tunnel, which lends itself readily to sub-division into the various sections, and partly by the availability of R.A.F-surplus aircraft propellers at a very low price. These propellers have four blades and their diameter is 13 ft; since their operating conditions differ from those for which they were designed, some experimental work will be required to determine the optimum blade pitch setting.

Each fan is driven by a 325 h.p. variable-speed induction motor, having a maximum speed of approximately 985 r.p.m. The drive is direct but some torsional flexibility and latitude in alignment are afforded by the fitting of an intermediate shaft, with a rubber disc type coupling at each end, between the motor and the fan. Each motor and fan assembly is carried on a fabricated steel structure, bolted to the floor, and the fan shaft runs in one ball and one roller bearing, both of which are of the heavy-duty type.

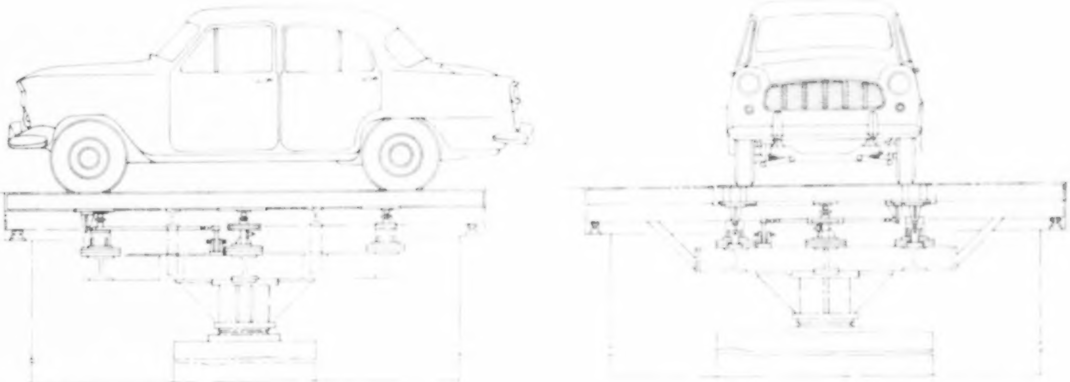
In the right-hand wall of the diffuser is an alternative entrance for vehicles, which measures 20 ft wide × 14 ft 6 in high. Both this and the frontal entrance are big enough to clear vehicles considerably larger than cars. Such vehicles can be accommodated on the chassis dynamometer, but for aerodynamic tests of them to have been practicable, considerable and costly increases in the dimensions of the tunnel and balance unit would have been necessary. However, half-scale models of large vehicles can readily be mounted on the balance. Because the hangar size imposed some restriction on the lengths of the various sections of the tunnel, it is envisaged that vertical guide vanes may have to be installed at some points to bring the air flow under full control and thus avoid inaccuracies.

Balance unit

The steel platform of the six-component balance unit has a diameter of 12 ft 6 in, and it is carried by four air bearings on its supporting framework. These bearings, the working diameter of which is 13 in, are fed with compressed air at up to 80 lb/in^2, depending on the weight of the vehicle under test. The maximum acceptable vehicle weight is 5,000 lb. Projecting downward from the middle of the supporting framework is a fabricated pedestal, the base of which carries the upper race of a large-diameter roller type thrust bearing of the kind used in cranes. The lower race of this bearing is mounted on a concrete base in the pit



The wind tunnel is constructed largely of timber, coated with fire-retardant paint. Visible at the far end is the reverse face of the entry shown on the previous page. The quarter-scale wind tunnel will be built in the empty space on the right



Above: Diagrammatic illustrations showing the disposition of the air bearings, load cells and strain gauge equipped cantilevers between the platform and the supporting structure of the aerodynamic balance. Below: The balance structure is revolved by gearing and a hydraulic actuator. In this view can be seen a horizontal strain gauge assembly and its connecting bar, also one of the air bearings, above which is mounted the load cell

under the tunnel. On the pedestal is a horizontal, toothed annulus, which is engaged by a pinion driven by a hydraulic actuator. By this means, the platform can be rotated through any angle up to 90 deg either side of its mean position; the setting can be accurately controlled to within ½ deg.

Between the platform and the structure are mounted the various elements for measuring the aerodynamic forces in the three planes. The arrangement employed is shown in one of the accompanying illustrations. For the measurement of the vertical components, load cells are mounted above the air bearings and embody the strain gauges that measure increments of load; a large steel ball is interposed between each load cell and a hardened pad beneath the platform, to ensure that all loading is axial. Only three of the four load cells are used at any one time.

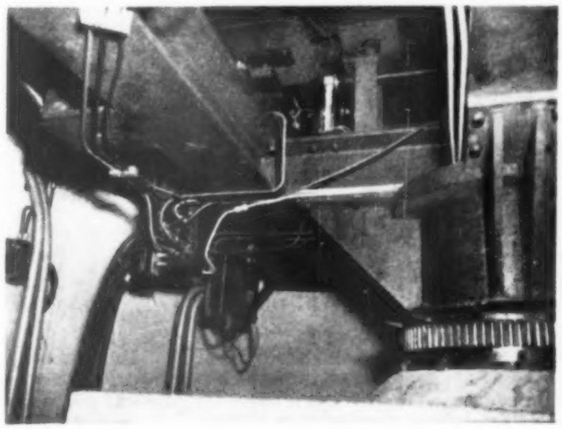
The horizontal components are measured by strain gauges on cantilevers mounted vertically on the structure and connected to the platform by horizontal steel bars. These bars are of considerable length, to minimize errors due to the effects of the vertical loading. There are three of these strain gauge equipped cantilevers, two of which measure longitudinal forces while the third measures lateral forces.

When the balance is not actually in use, the platform clearly has to be locked in its neutral position, to avoid damage to the delicate mechanism. Locking is effected by 26 hydraulic jacks, spaced round the circumference of the platform. The jacks are mounted on abutments projecting inward from the walls of the pit.

Chassis dynamometer

It is envisaged that the main use of the chassis dynamometer, which can accommodate axle loads of up to 8 tons, will be the investigation of cooling problems and measurement of power outputs at the wheels of the vehicles. For these purposes, its advantage over the trailer type of dynamometer lies in the accuracy with which the air speed parameter can be measured and varied and in the greater stability of the conditions. Adjustments can, of course, be made to the dynamometer load setting to simulate changes of vehicle weight, rolling resistance and gradient.

The dynamometer itself is an orthodox Ward-Leonard unit; it has an absorption capacity of 250 h.p, a motoring output of 150 h.p. and a speed range of 1,500 to 4,000 r.p.m. It is coupled to a three-speed gearbox, which in turn is connected to a two-speed rear axle to drive the rollers; thus there is a choice of six speed ranges. The rollers are of fabricated steel construction and are 5 ft diameter. They



are sufficiently wide to accept vehicles having any track from 3 ft to 6 ft, and their maximum designed peripheral speed, in the highest overall ratio, is 120 m.p.h. Vehicles with twin rear wheels can be accommodated by removing the outboard wheels.

Two trunnion bearings, one on each side, carry the banjo casing of the axle on its mounting block in the pit. The casing is fitted with a duplicated weighbeam arrangement, to enable the torque to be measured when the dynamometer is driving or is being driven. Each weighbeam is linked to an N.A.C.A. type air cell, which converts the applied torque into a pressure that can be measured by a manometer.

When a vehicle is mounted on the dynamometer, it is prevented from moving by chocks clamped against the front wheels and secured to the floor by through-bolts. Because of the necessarily short distance between the balance unit and the dynamometer, sections of the locating channels for the bolt heads are embodied in the balance platform as well as in the main floor. The platform jacking system mentioned earlier is strong enough to resist the loading applied when a large vehicle is on the dynamometer or is being moved to or from it.

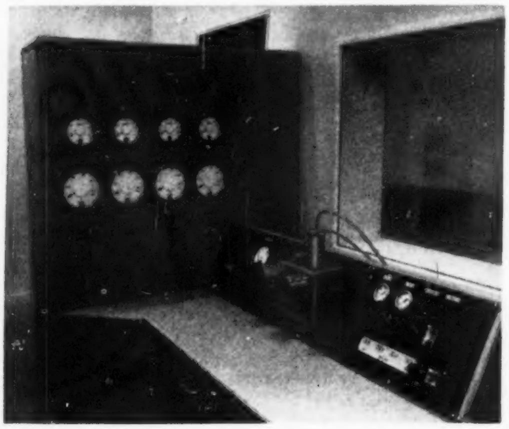
Control system and instrumentation

The control room is alongside the right-hand wall of the working section of the tunnel. In this wall are three large windows, double-glazed for sound insulation. To avoid misting, the sills between the sheets of glass are covered

with silica gel. Controls and instrumentation are divided into three main groups: the first is for the fans, the second for the balance unit and the third for the dynamometer.

The method of fan control employed was dictated partly by economic considerations. Since the ideal arrangement, a coupled and infinitely variable system, would have been undesirably expensive, each motor has its own multi-speed control and tachometer. The control provides a choice of eight speeds, more or less evenly spaced. Should an intermediate air speed be required for any particular reason, it might be obtained by running the various fans at different speed settings. It is considered that the maximum air speed of 80 m.p.h. should be high enough for all normal purposes; extrapolation can, of course, be employed to obtain additional data regarding higher speeds.

For showing the approximate air speed through the working section, a dial indicator of conventional aircraft type is installed. Precise measurement, however, is effected by means of a commercial micro-manometer, the basis of which is a float in a column of water. An optical projection system provides the necessary magnification, and the reading is given on a scale engraved on a glass screen.

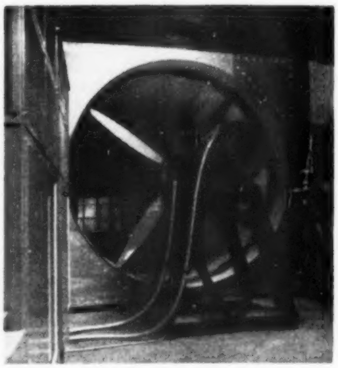


Part of the control room: on the left is the instrument and control panel for the fan motors; in the middle of the horizontal panel is the air speed micro-manometer, next to which are the balance controls

For calibrating the tunnel, a normal pitot-static unit on a stand is at present employed to pick up the pressure differential applied to the manometer. In due course, a permanent tapping will be taken from a convenient point in the tunnel. This tapping will be correctly sited in relation to the balance, so a correction factor will have to be evaluated for test work on the dynamometer, because of air flow differences between the two portions of the tunnel.

Initially, a manually operated balancing-control will be employed to obtain a reading from the various strain gauges. Provision has been made, though, for an automatic system to be installed, whereby pressure on a single button will cause the readings to be obtained in sequence. Whereas the instruments for indicating the vertical forces have only one operating range, those for the horizontal components have high-sensitivity and low-sensitivity ranges. The high-sensitivity range is necessary for accurate measurements at small angles of yaw, or at low air speeds, when the horizontal forces are at a minimum.

In the dynamometer section of the control room are the controls and instruments for the dynamometer itself and the manometers for the measurement of driving and driven torque. These manometers, too, have both high-and low-sensitivity ranges. Initially, adjustments to represent variations of the parameters will be made manually, but an automatic control system will be installed at a later date, to facilitate the carrying out of sequential tests.



Displacement of the air is effected by four 13 ft diameter, aircraft propellers. Each is driven by a 325 h.p. electric motor with eight-speed control equipment

Quarter-scale wind tunnel

This tunnel will be built on generally similar lines to the full-size tunnel, though there will naturally be a number of differences, apart from those of dimensions. For example, a single fan will be employed and will be driven by a 50 h.p. motor fitted with infinitely variable speed control. The maximum air speed through the working section will be 90 m.p.h, and the balance set-up for the platform will embody a system of strain gauge links similar to that of the larger tunnel. Air bearings will not, however, be necessary because of the lower weight of a model in relation to the aerodynamic forces. The smaller tunnel will have its own control room, so that secrecy can be maintained by member companies wishing to test new designs. The overall length of the tunnel is 50 ft and the working section measures 12 ft 6 in long × 6 ft 9 in wide × 3 ft 4½ in high.

Projects and operation

As is the case with other M.I.R.A. facilities, the wind tunnels will be used both for the Association's own research work, the programme for which is decided by its various committees, and for the investigation of special problems on behalf of individual member companies. No information is yet available regarding the second of these activities, but two internal projects are envisaged for study once the tunnels are fully operative. One is a general research on stability phenomena, including the effects of tail fins.

The second project concerns the aerodynamic efficiency of cooling systems. Because of the obstructed shape of the engine compartment and the uncontrolled air flow, particularly on the downstream side of the radiator, the cooling systems of vehicles exert a considerable drag. In contrast, those of aircraft frequently provide a small thrust, by virtue of their aerodynamically correct design. This thrust is not, of course, something for nothing but is obtained by virtue of the transfer of heat energy to the air passing through the system. It is doubtful whether the installational complexities of a motor vehicle would enable cooling system drag to be eliminated, but a worthwhile reduction is thought to be practicable without being uneconomic.

Owing to local restrictions in respect of the consumption of electrical power, operation of the larger tunnel at full speed will for the present be permissible only during the night. A half-speed limit has been set for daytime usage and will apply until increased generating capacity becomes available, which, it is hoped, will be in two or three years' time. Because of the much lower power requirement of the smaller tunnel, its use will not be restricted in this way.

Valve Spring Production

The Mechanization of the Old Craft of Spring Making to Meet Current High-Volume Requirements is Exemplified in the Works of George Salter and Co. Ltd.

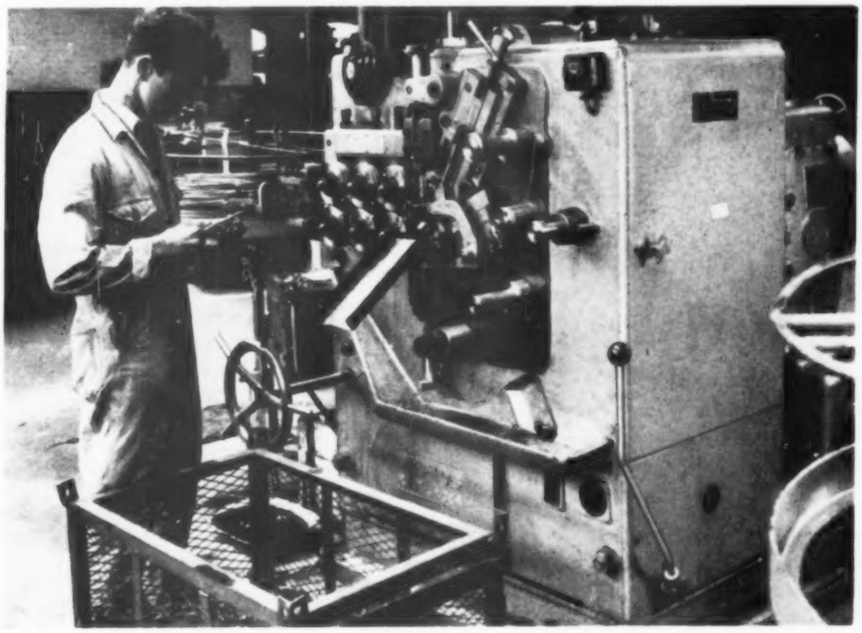
TODAY no motorist, outside racing or sporting activities, suffers perturbation on account of the valve springs of his engine, and his unthinking trust in this ubiquitous and inexpensive component is not misplaced. An attempt to estimate the number of times a spring has closed a valve while running the vehicle over, say, 1,000 miles on the road is a not uninteresting exercise, and the magnitude of the resulting figure is likely to cause amazement and some respect. Fifty years ago, valve spring failures were fairly common and not infrequently resulted in serious damage to the engine. In some quarters, overhead valves were decried owing to the danger of the valve falling into the cylinder "when the spring breaks". Some early engines —aircraft, automobile, and motorcycle types—it may be recalled, persisted in the use of side-type valves for that reason. Design and development was mainly on empirical lines, material was not yet specially developed for the purpose, nor was it of such precise or consistent specification, and manufacture was by craftsmen at the bench.

Spring making was an important craft and manufacture was concentrated in a few centres in the Black Country, Yorkshire and Lancashire. Typical of some of the larger concerns specializing mainly in spring making was the firm of George Salter and Co. Ltd., of West Bromwich, Staffordshire, which was originally founded in the year 1760. They first produced valve springs for motor car engines in 1901, and fifty years ago were well-established producers of valve springs for the early car manufacturers, including Lanchester and Rolls-Royce.

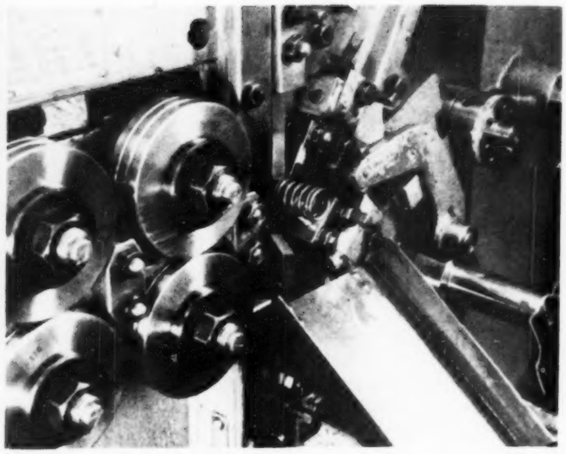
Early springs were made from carbon steels, which possessed the main requirement of high tensile strength. They were wound by hand on a mandrel in the manner shown in one of the illustrations, hardened, and "let down" by immersion in a molten-lead bath. The spring maker hooked the wire over a dog at the left of the mandrel, wound a closed coil, then hung over the mandrel a weighted hook—termed a spacer—of a cross-section appropriate to the required pitch of the spring, wound the specified number of free turns, wound a final closed coil, severed the stock wire, slipped the spring off the mandrel, and trimmed the ends. Current practice, when a new type of spring was required, was for a firm to order half-a-dozen or a dozen of the springs as samples, try them in operation on an engine, and then either confirm or modify the design before an order was placed.

As in other fields of activity, the impact of World War I and the associated rapid development of motor vehicles and aircraft had a marked influence on the industry. Government specifications regarding materials and performance were tighter, more precise, and more comprehensive, than hitherto, and A.I.D. inspection was instituted. In 1916, the American specification for chrome-vanadium steel stock was adopted. The use of alloy steels markedly changed workshop methods; heat treatment in particular.

In World War II, Government specifications were rigidly imposed and, in fact, were among the first standards to be laid down for British industry. Not until 1947 did the British Standards Institution issue its first standard on springs. Research was undertaken and accumulating scientific knowledge is displacing empirical methods in both design and application. This is not to imply that craftsmen have disappeared. They are still very much in evidence in a spring shop. It is not without interest to note that Salter still make valve springs by hand for certain applications, in



One of a battery of Wafios automatic coiling machines. The operator is gauging the free length of a spring to check machine performance



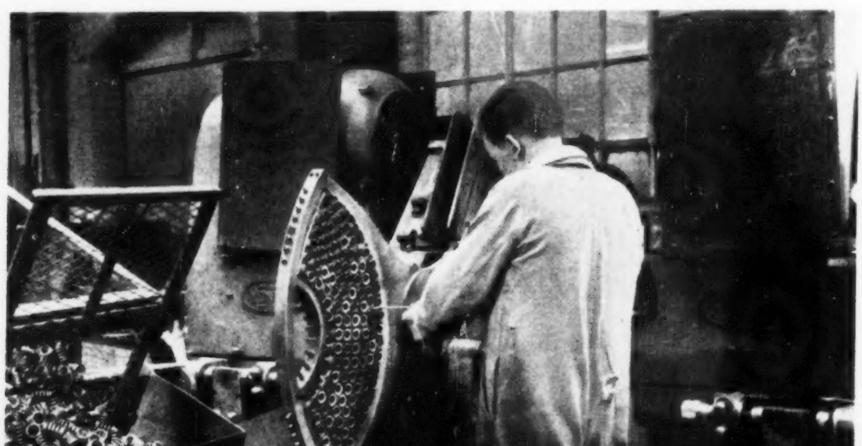
The contrast in old and new methods of coiling springs. Left: the long-established manual method of winding on a mandrel. The weighted spacer is shown in use. Right: detail of the feed rolls and tooling set-up on the Wafios automatic machine

batches of considerable numbers. For example, the valve springs for one aircraft-engine manufacturer have been made by the firm for more than 30 years. Today they still supply hand-made springs for current versions of these engines, conforming to the severe standards of the A.I.D. The sequence of operations on these springs, of DTD-5A material, is as follows:

(1) Coil
(2) Heat, for stress relief
(3) Cut off, both ends
(4) Grind, both ends
(5) Chamfer, internal diameter of both ends
(6) Shot-peen, all over
(7) Linish, both ends
(8) File, both end tips
(9) Circumferential grind, both ends
(10) Scrag, to establish solid length
(11) Finish, correct to specified free length
(12) Reheat, to normalize
(13) Load test, to establish loaded length
(14) Aluminium paint
(15) Coat with lanoline

It is not higher standards of quality, precision, or performance that defeat the skill, ingenuity, and resource of the craftsman but the sheer magnitude of the numbers required at a high rate of production. The rapid development of the internal combustion engine, particularly in the automobile and aircraft industries, accelerated the advent of mechanization in spring manufacture and continues to foster it. Valve springs for the engines of a range of automobiles in continuous production are required in multiples of a million per annum.

The successful operation of a valve spring depends mainly on two factors; correct design and the use of the most suitable material. Design principles are now established, and given the fundamental data—including information on cam profile, applied velocity, applied acceleration, and out-of-balance weight—the designer can determine the required



Rowland twin-disc machine for grinding the spring ends. One workholder is here being unloaded while the other is in the grinding position

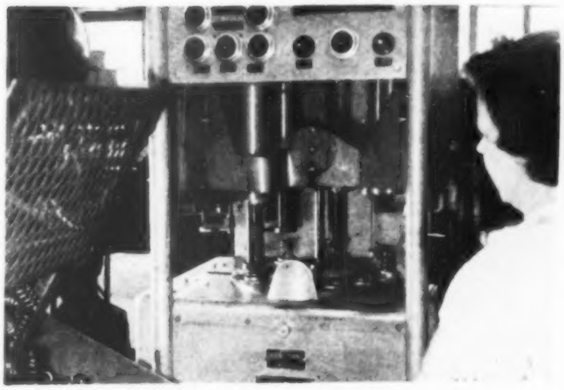
characteristics and arrive at the optimum spring. The phenomenon of surge, however, will remain for consideration.

Valve spring surge, which may be excited by a variety of factors in engine design and operation, is the vibration of the free, central coils at the natural frequency of the spring. A group of these coils move together to and fro along the spring axis and impose dynamic stresses in the spring which are far in excess of those imposed at low speed. Various expedients can be employed to overcome surge; that most commonly used is the provision of so-called "damper coils", of relatively closer pitch, at the spring ends. These have the effect of changing the frequency of the spring immediately the surge wave becomes effective. A small machine, fitted with a camshaft designed to reproduce specific operating characteristics, is used to ascertain the initiation of surge and to check that a modification in design is effective. Investigations are made with the aid of a stroboscope.

Standard specifications, the product of years of research, enable a designer to select appropriate material for a given set of conditions, but it is considered essential that wire for high-duty applications is checked to ascertain that it conforms to requirements. Normal laboratory tests are conducted on all bundles of wire received from the suppliers before acceptance into stock, lengths being cut from each end of a bundle for that purpose. All stock bundles are protected in store by a wrapping of hessian. The wire, generically termed "of valve spring quality" is supplied in tempered condition.

A continuous programme of fatigue research is carried out to evaluate the effects of different heat-treatments, shot-peening operations, and surface finishes. Fatigue tests are also made on any new type of material. Typical test machines have twelve test stations, each operating at 1,400 rev/min. For differing applications the test runs of springs may be from seven to ten million oscillations.

Coiling is done on batteries of automatic machines, mostly of German origin. Illustrated is a Wafios machine, coiling valve springs. The wire is drawn from the reel and through



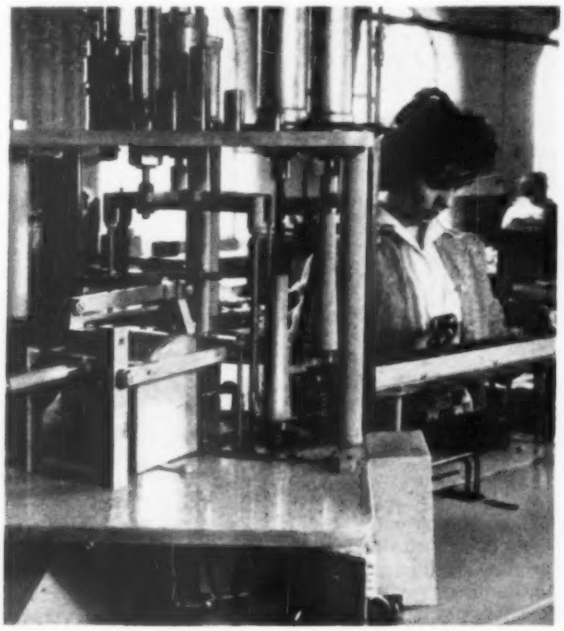
Production testing of valve springs on a German Probat machine. The loading stations are at the right front, followed by two scragging stations

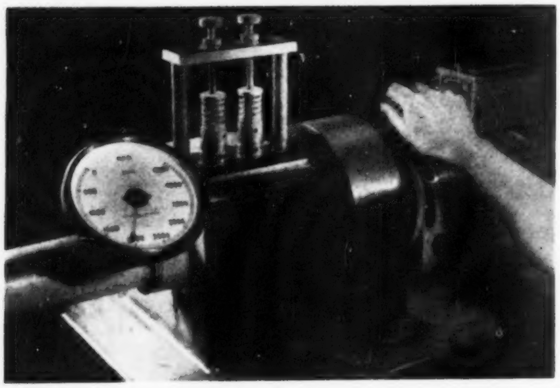
two sets of straightening rolls, arranged in planes normal to each other, by feed rolls that project it over a stationary half-mandrel. Arranged radially around the mandrel are two coiler points which close wind, a spacer point which controls the pitch of the free turns, and a cut-off tool which, at the completion of coiling, crops the spring from the stock wire. The spring is slipped off the mandrel and falls down a chute and into a basket-type container. Production is batched, and typical runs are for 100,000 springs. They are handled and sequenced through following operations in the baskets, which each have a capacity of 4,000 springs.

As coiled, the wire is more highly stressed on the inner diameter than on the outer diameter, and the next operation is a heat-treatment to stress relieve. This has a tendency to increase the wind-up by a fraction of a turn. Then the ends of the spring are ground normal to the axis. At present this operation is carried out on a battery of Rowland twin-disc grinders with pivotally mounted, diametrically opposed, sector-shaped workholders. As shown, one sector is

Unloading a "basket" of valve springs, approximately 4,000, after shot-peening in a Spenstead machine

Deadweight testing of valve springs on a specially developed Salter machine. Feed is by a walking beam system





Variable speed test rig for investigating and demonstrating surge in valve springs. At left and right are surging and corrected springs

unloaded and reloaded while work in the other is being ground. The wheelheads are given a short oscillating stroke across the work whilst they are fed inwardly to micro-trip switches, on engaging which they automatically retract. In the near future it is likely the springs will be ground on a continuously operating twin-disc machine furnished with a large diameter circular workholder slowly revolving between the two wheels which are maintained at a constant spacing with automatic compensation for wear.

After grinding, the springs are shot-peened all over for a period of from 20 to 30 minutes in a Spenstead machine of the tumbling barrel type. In addition to its primary function, shot-peening is also of importance in producing a uniform surface finish free from sharp scratches or indentation that could be expected to form stress-raisers. The final operation is a second stress-relieving treatment, from ½ to 1 hour at 280 to 300 deg C.

Every spring is individually tested and in view of the numbers involved, this important operation is necessarily mechanized. Until recently large batches of springs were tested on German Probat machines. Springs were manually loaded into an apertured indexing disc that progressed them through a number of radially disposed stations. They were twice, successively, scragged and then passed to spring-loaded anvils and tested for loaded height against micro-switch trips. Selectively, they were delivered to "Pass", "Long" and "Short" bins.

Currently, this work is being transferred to new machines developed and built in the Salter organization. On these machines, as shown, springs are manually loaded into a channel guide and fed to the work position by a walking-beam mechanism. There they are picked off individually by a hooked indexing spider that carries them round a radial series of stations. The sequence is similar to that of the Probat machines, the spring being twice scragged, transferred or rejected for shortness under load, and passed or rejected for excess length under load. An important difference, however, is that loading is imposed by dead-weight instead of by spring.

Mechanical loading of springs from bulk containers, in this and other operations, has so far eluded practical solution. The propensity of interengagement of coils, sometimes into masses of considerable number, is not overcome by commonly used methods of separation. Vibration, reciprocation, or tumbling is likely to consolidate an engaged mass.

Rotary Compressors

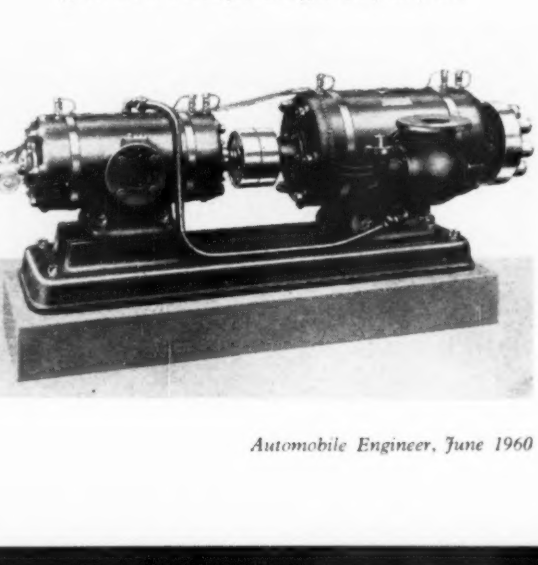
With more than fifty years experience in designing and building large-capacity reciprocating compressors, Bellis and Morcom Ltd., Birmingham, 16, now manufacture single-stage and two-stage M.P.R. rotary compressors of the sliding-vane type, under licence from the French company. The operational range is from 20 to 40 lb/in² in a single stage and from 70 to 110 lb/in² for the two-stage machines, with outputs of from approximately 100 to 600 ft³/min, thus extending their range of reciprocating compressors to cater for small-volume requirements.

Design is straightforward and construction is robust. The rotor, integral with the shaft to obviate shrink fits, is machined either from high-grade bar or a forging, depending on size. Free-sliding vanes are of a special resin-bonded material. Both the cylinder, with integral intake and delivery branches, and the head castings, carrying the mainshaft bearings, are jacketed for water cooling. Heavy-duty, high-precision, roller bearings support the shaft which is fitted with self-adjusting plastics seals of the axial type. Lubrication of cylinder and bearings is by an oil pump driven from the free end of the shaft, with a sight flow glass and individual adjustment at each point.

Standard units have one or two stages in line, but other arrangements of cylinders or stages are possible. Normally, two-stage machines are furnished with a vertical intercooler, mounted alongside, to lower the intake air temperature to the second stage and to remove some of the moisture present in the air. A direct-coupled, constant-speed, AC motor is the recommended type of drive, but almost any form of drive can be employed, with vee-belt or gear transmission if necessary. The coupling drive is of the shear-pin type.

Since most electric drives are likely to be by a constant-speed AC motor, control is usually by means of an intake valve that automatically shuts off air to the compressor when the selected pressure has been exceeded by from 3 to 5 per cent and reopens when the pressure has fallen to normal. Thus the machine, when operating, is either at full load and efficiency or is running light. An automatic release gear opens the delivery branch to atmosphere to keep the light-running power at a minimum. Relay mechanism, operated from the discharge side of the delivery non-return valve, actuates the intake control valve and is adjustable to enable the operating pressure of the control valve to be varied.

Typical M.P.R. two-stage, vane-type, rotary compressor



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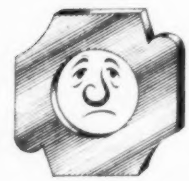
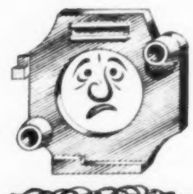


—Because the basic idea behind a component part must be adapted to serve the function of the whole.

Add further difficulties



—Actually you don't need to add them—they come by themselves! And the original idea often turns out to be a knotty production job.

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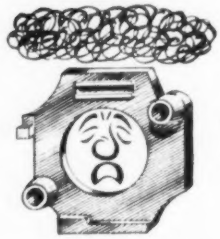

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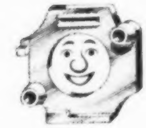

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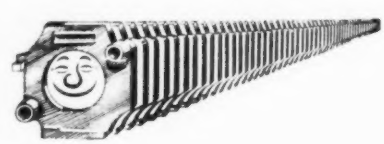

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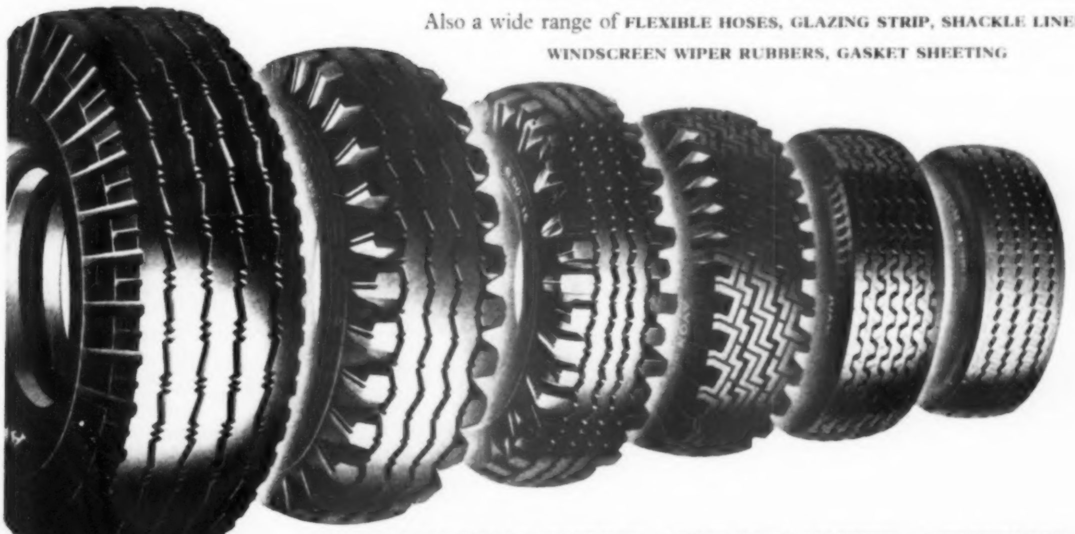

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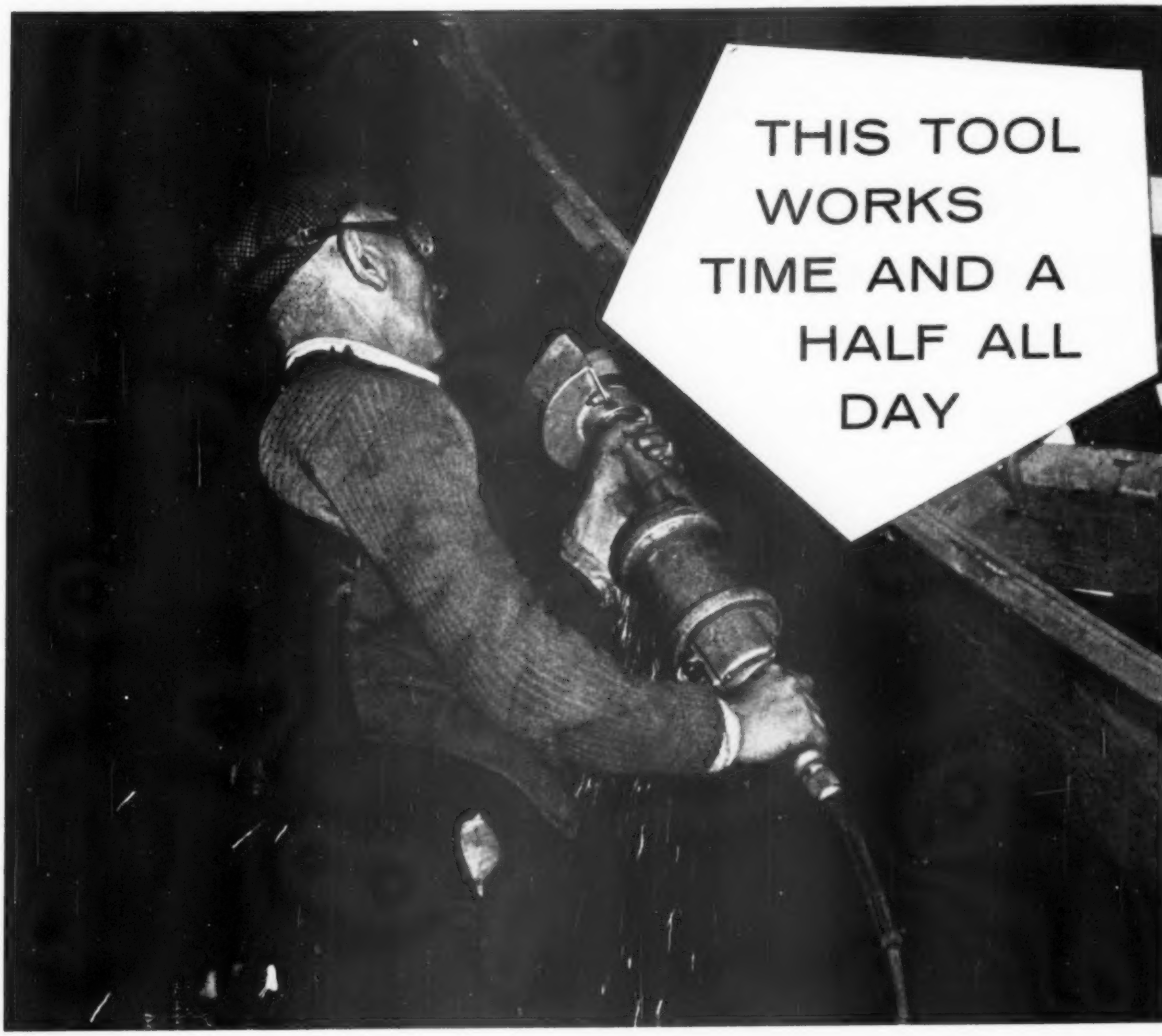

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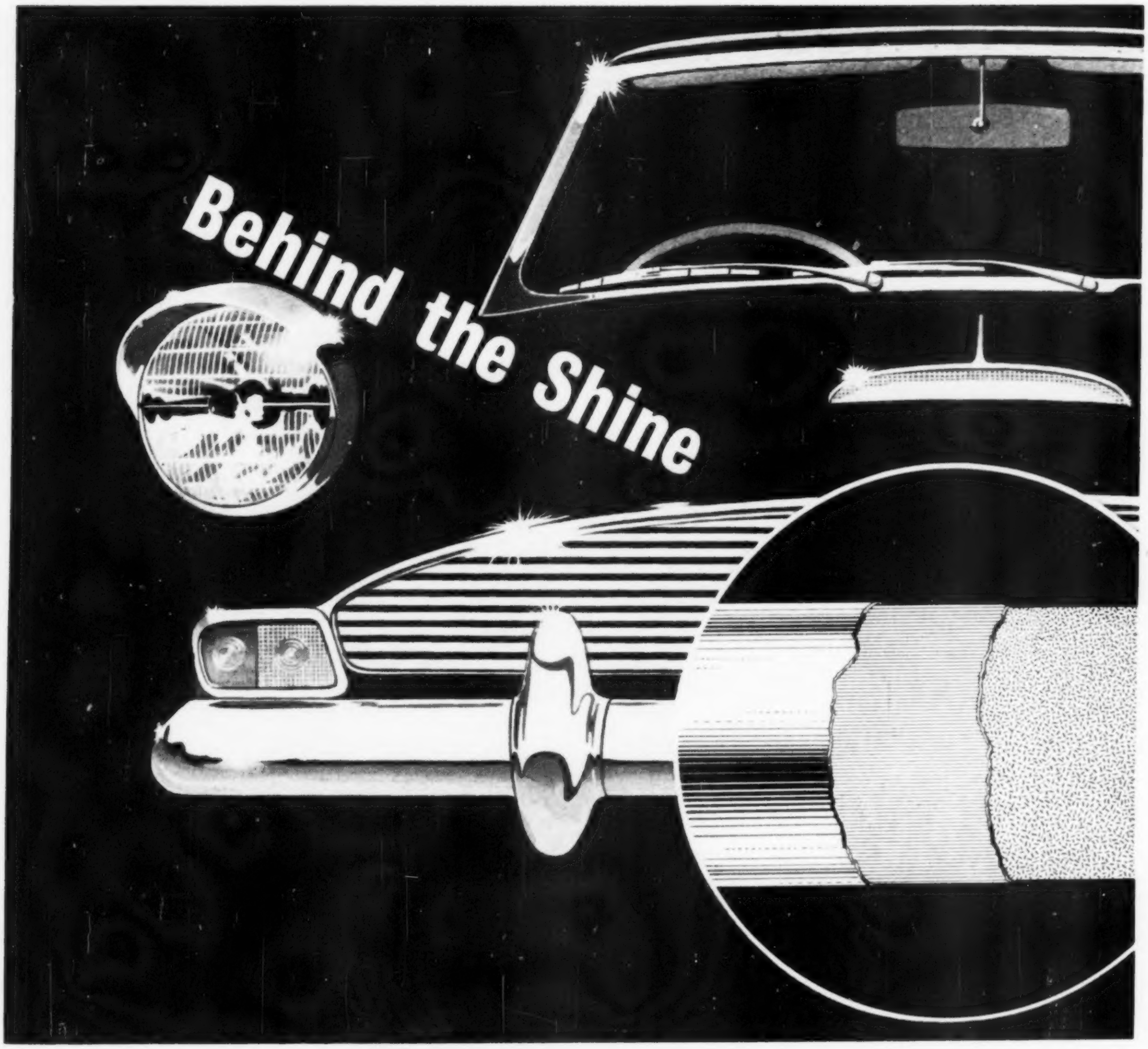

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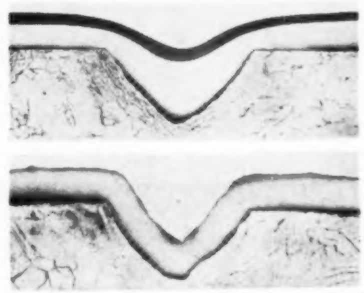

The above photomicrographs demonstrate the levelling effect of Harshaw Duplex Nickel as compared to that of conventional grey nickel. Top: Perflow-Perglow Duplex Nickel-depth of scratch 2·7 mils.
Bottom: Grey nickel-depth of scratch 2·7 mils.

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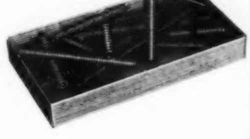

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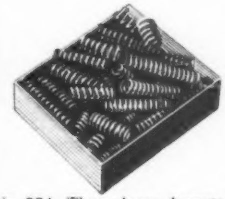

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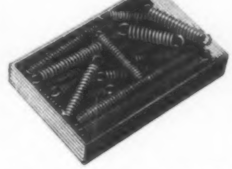

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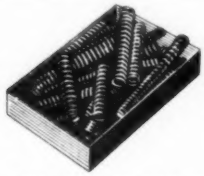

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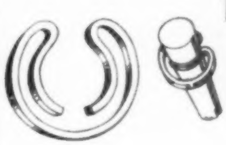

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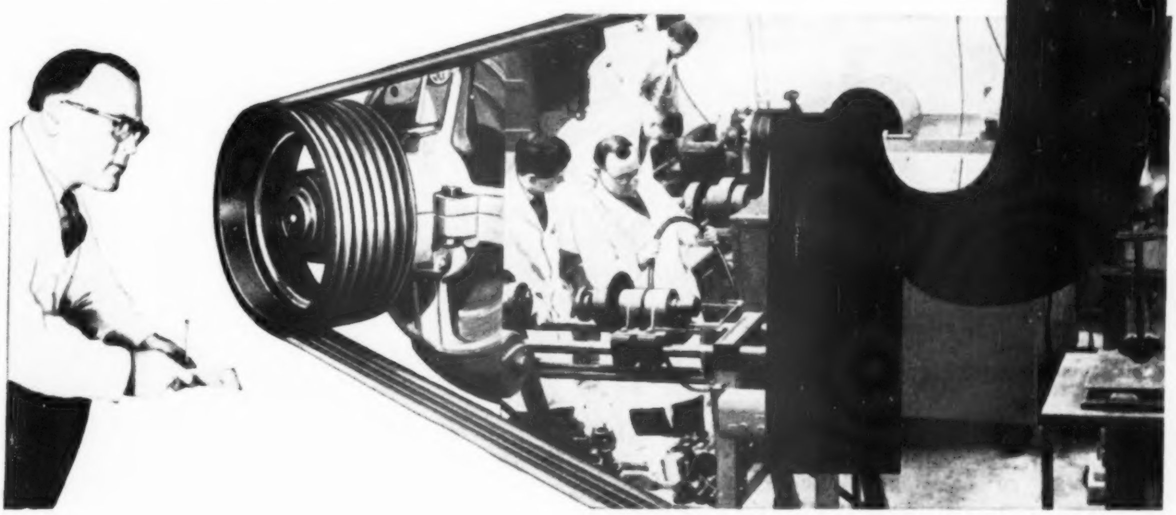

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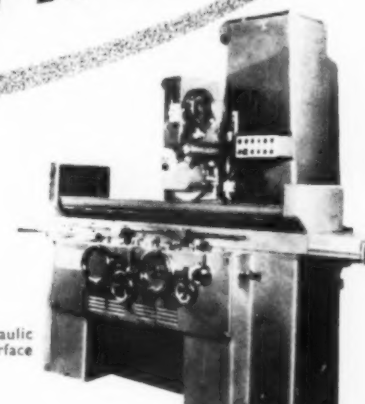

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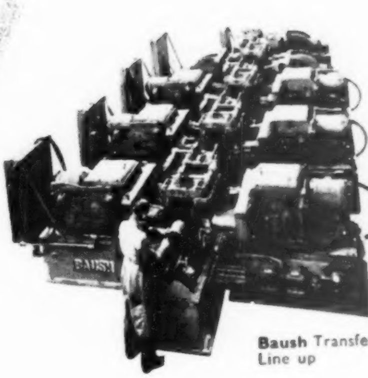

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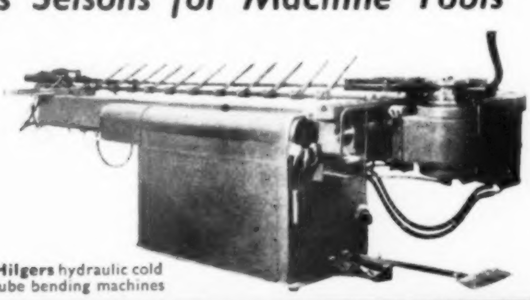

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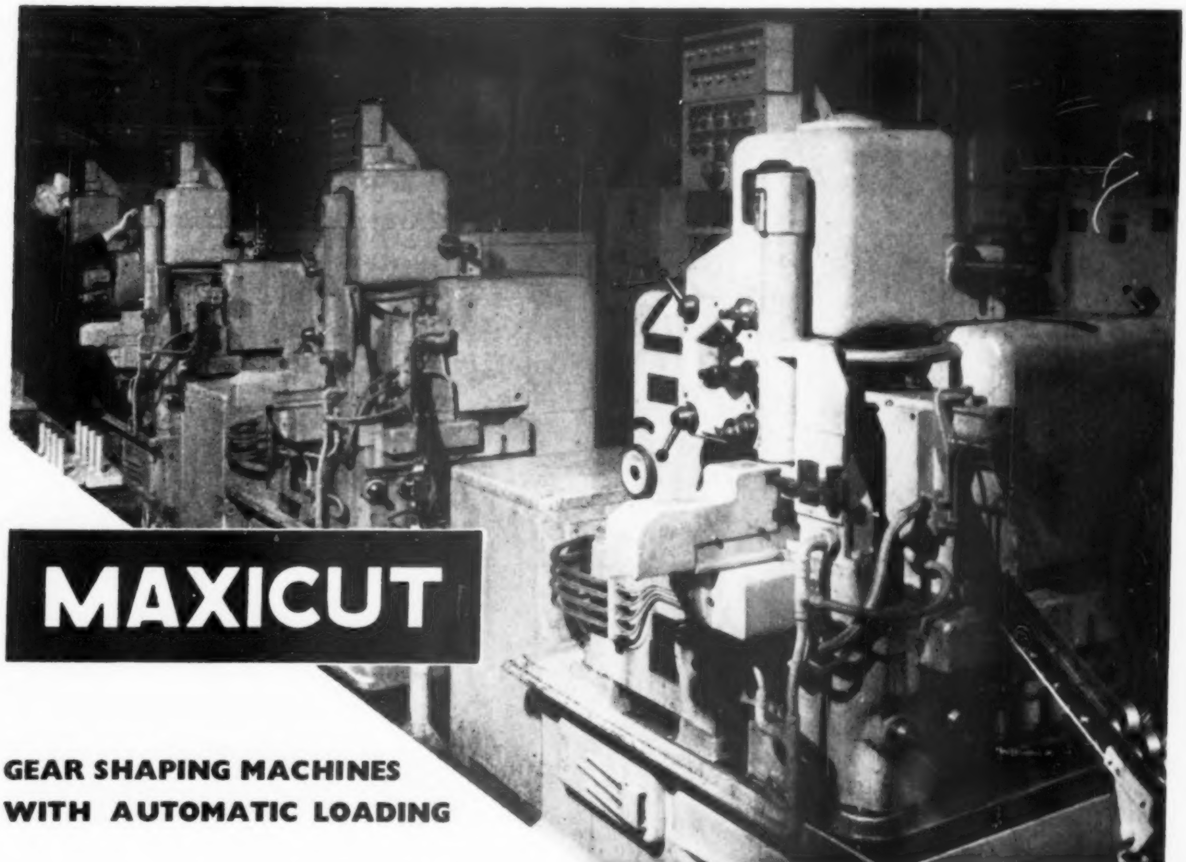

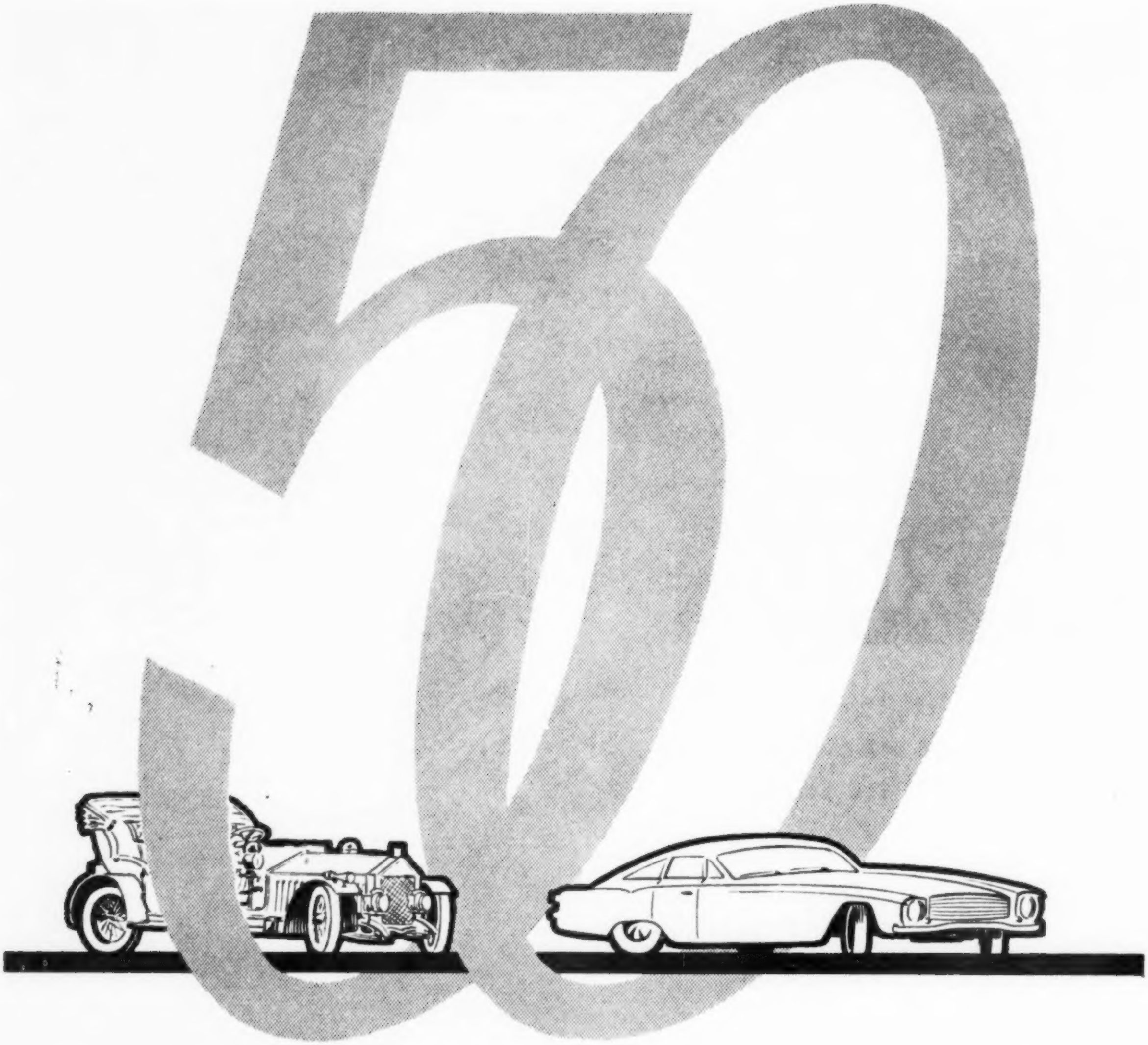

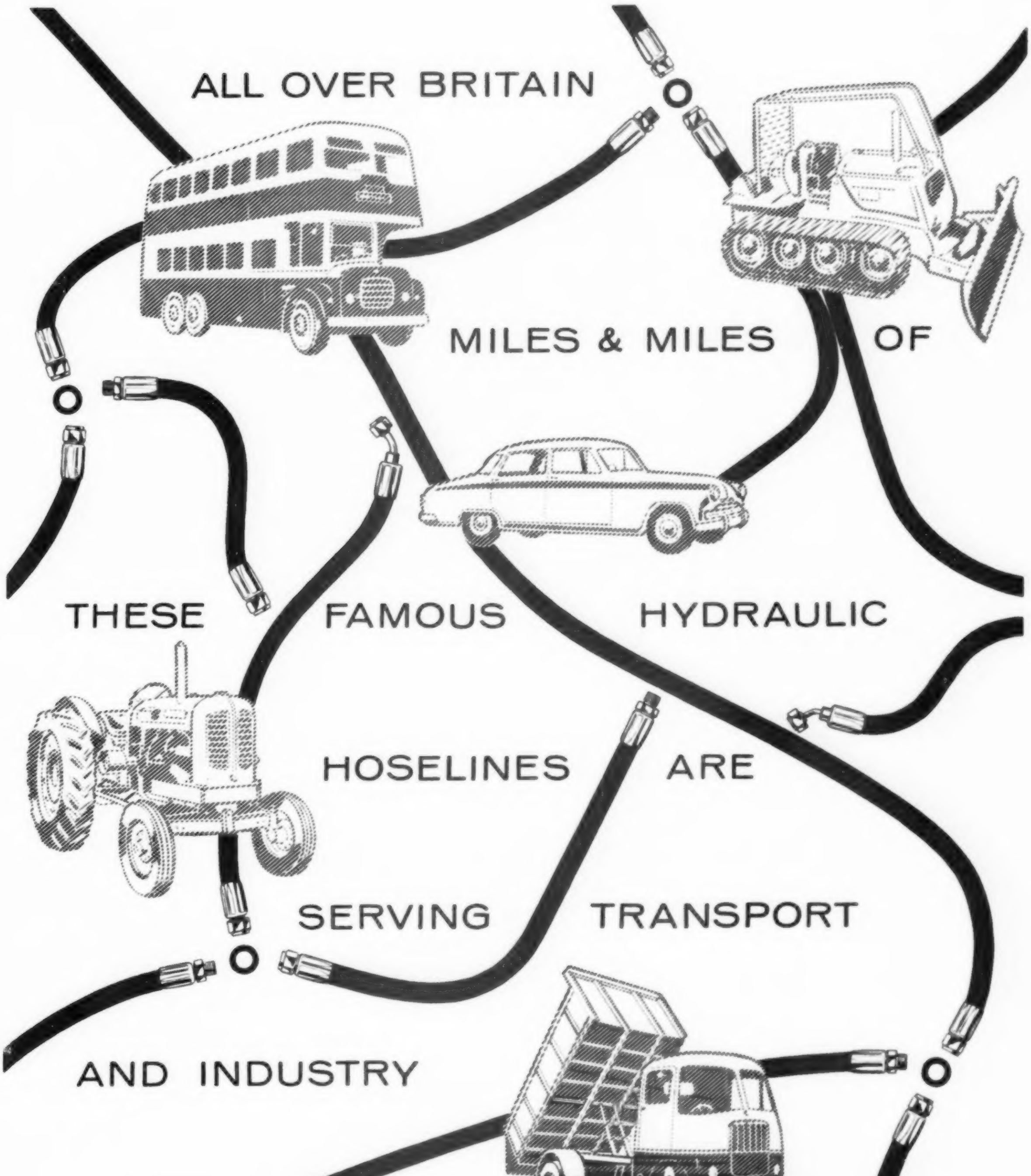
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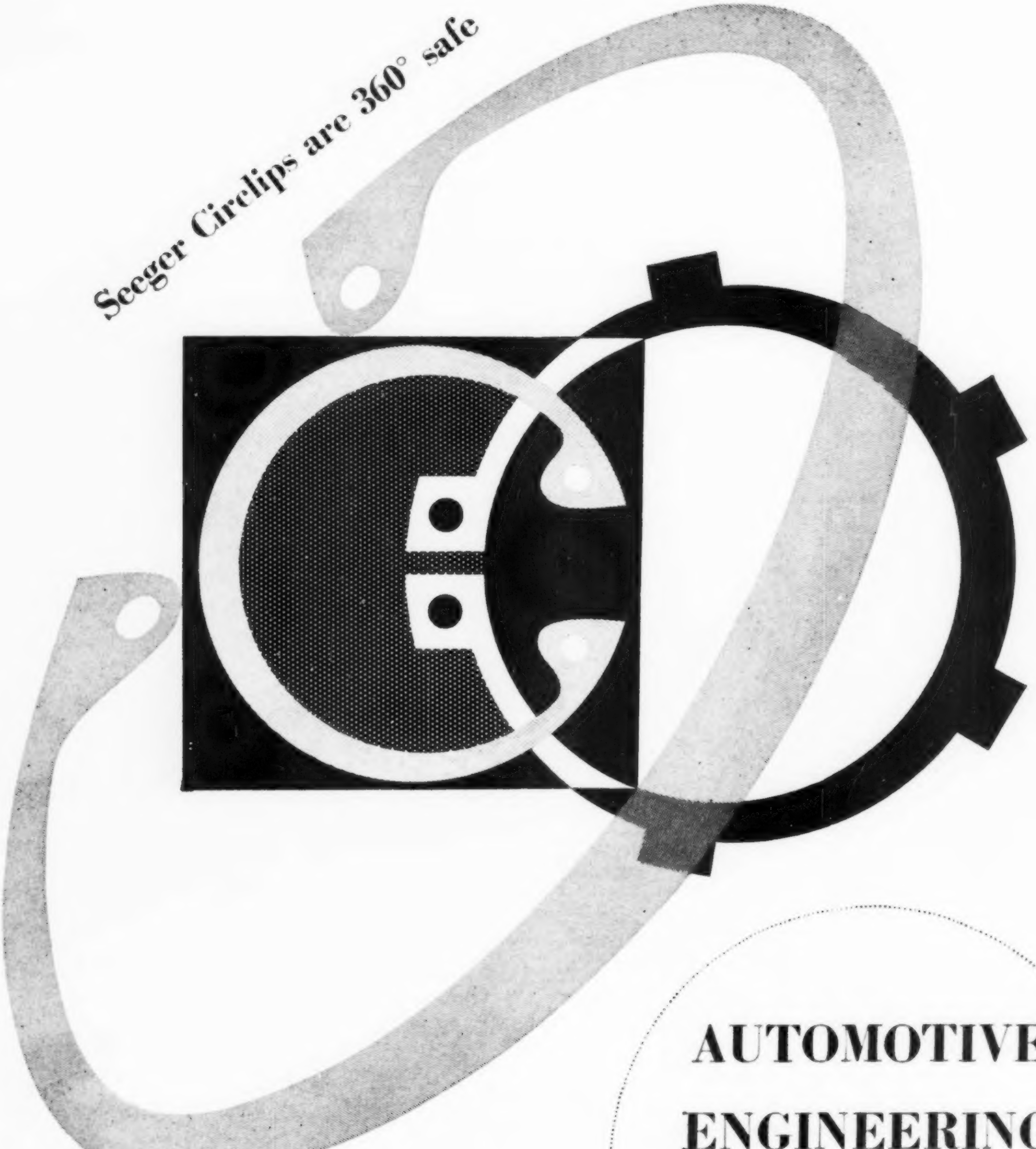

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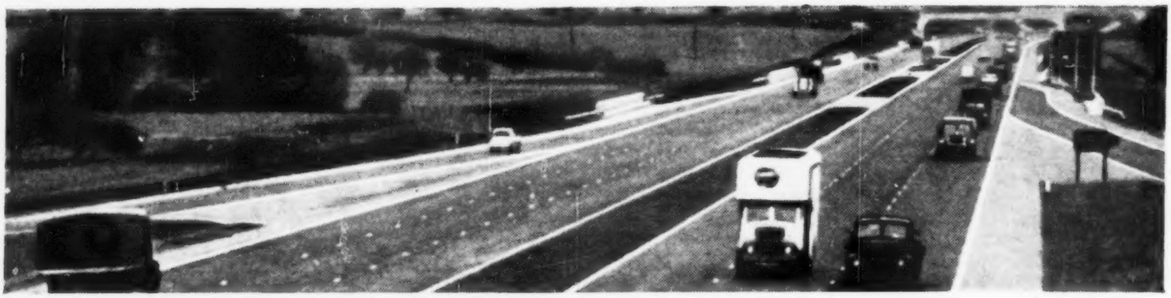

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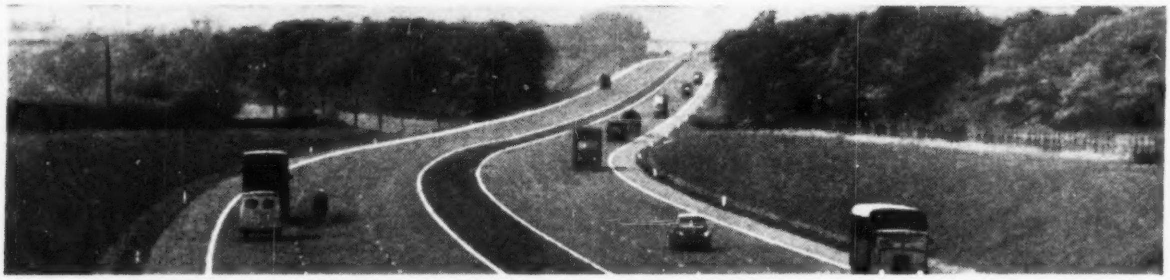

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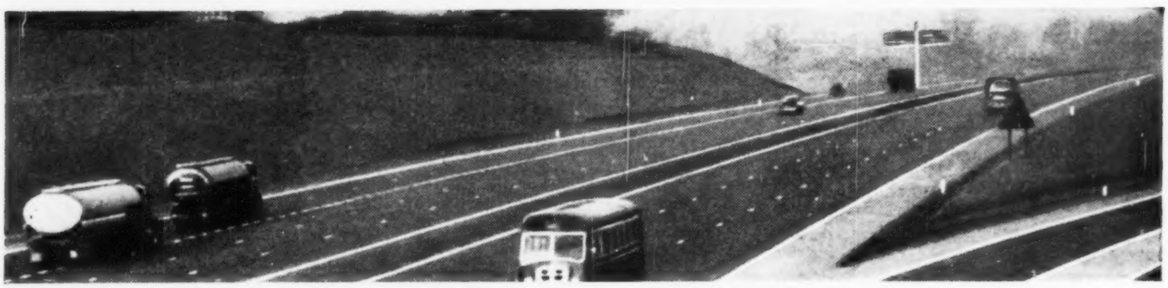

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The excellent performance of these bi-metallic pistons, plus the extra length of life (especially ring groove) over a long period has convinced us that we were correct in standardising on them for all our engines. This, in turn, has decided us to standardise on your Al-Fin pistons as original equipment also, and therefore on all new vehicles these pistons will be specified, and by using them from the outset we are convinced we shall benefit".

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The new motorways have already caused a spectacular number of engine breakdowns. High speed for hour after hour is just *too* much for many engines . . .

Fortunately, AL-FIN armoured pistons can take the hardest possible driving and still *outlast ordinary pistons 2 to 1.* The AL-FIN unique construction is incredibly tough. Satisfied users all over the United Kingdom have proved for themselves AL-FIN durability and economy.

Remember, you will get twice your normal mileage on every vehicle fitted. This means real economy in operating costs. Keep your lorries rolling and earning with AL-FIN armoured pistons.

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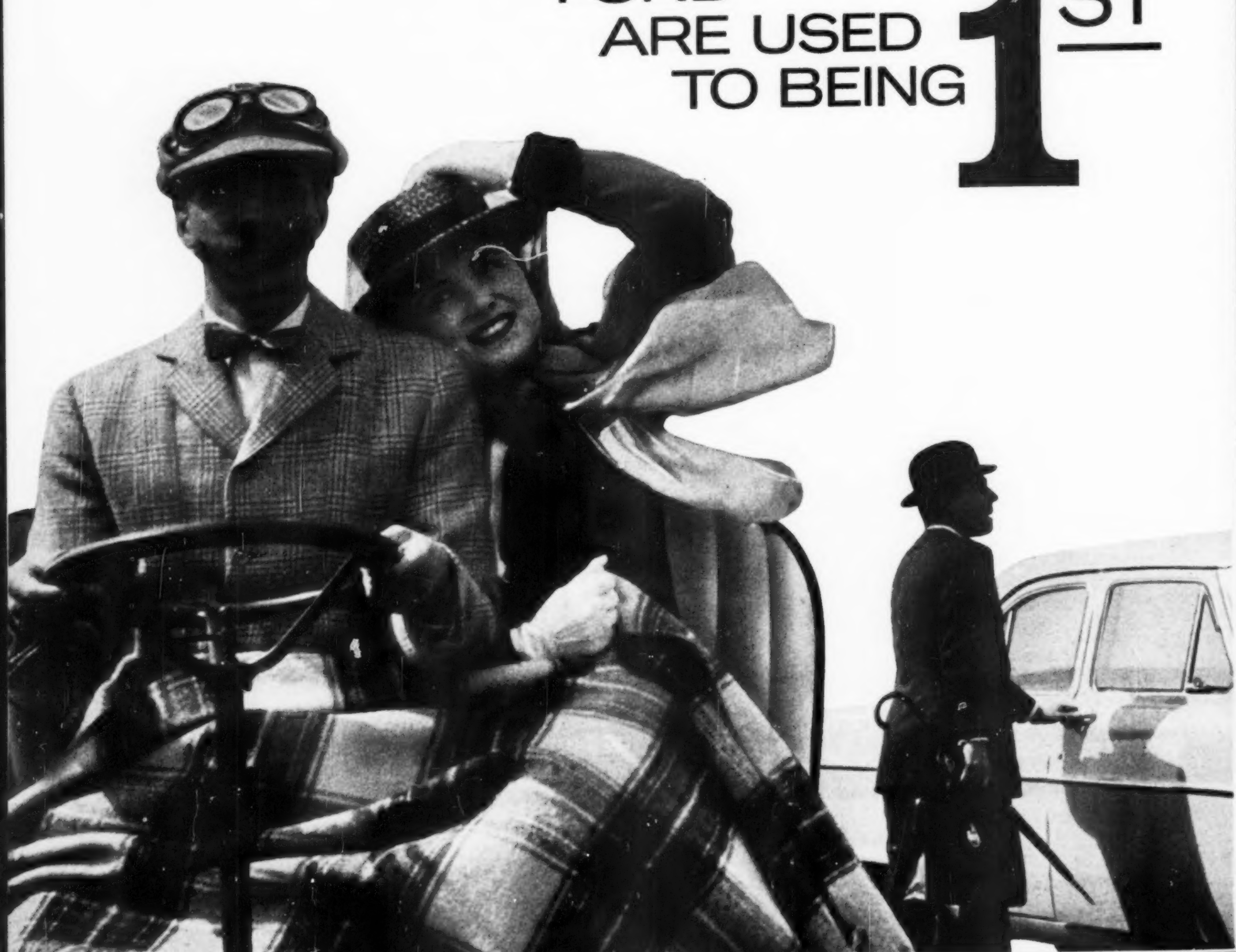
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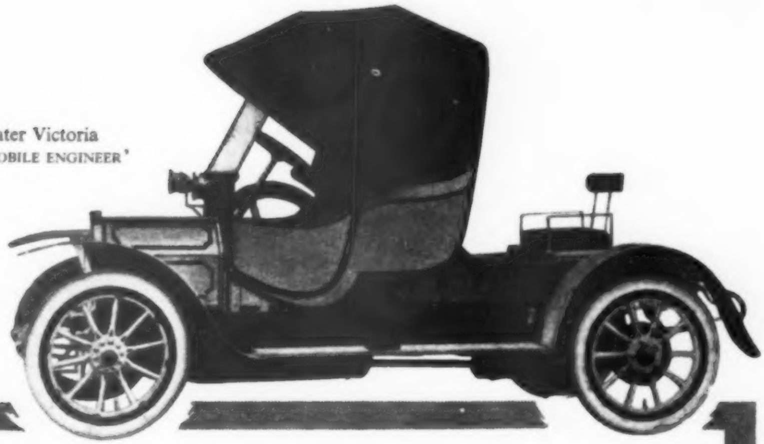

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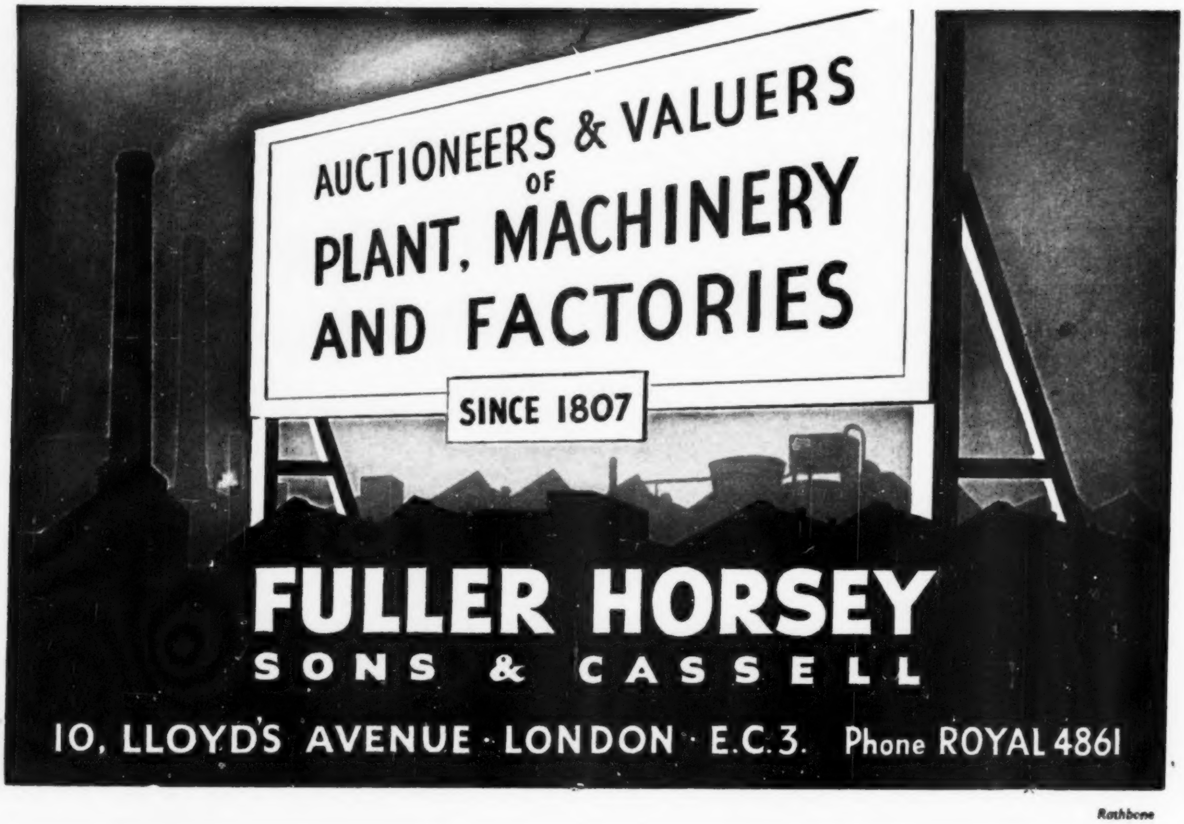

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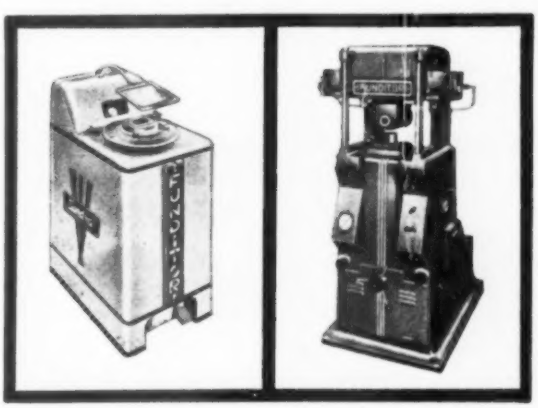

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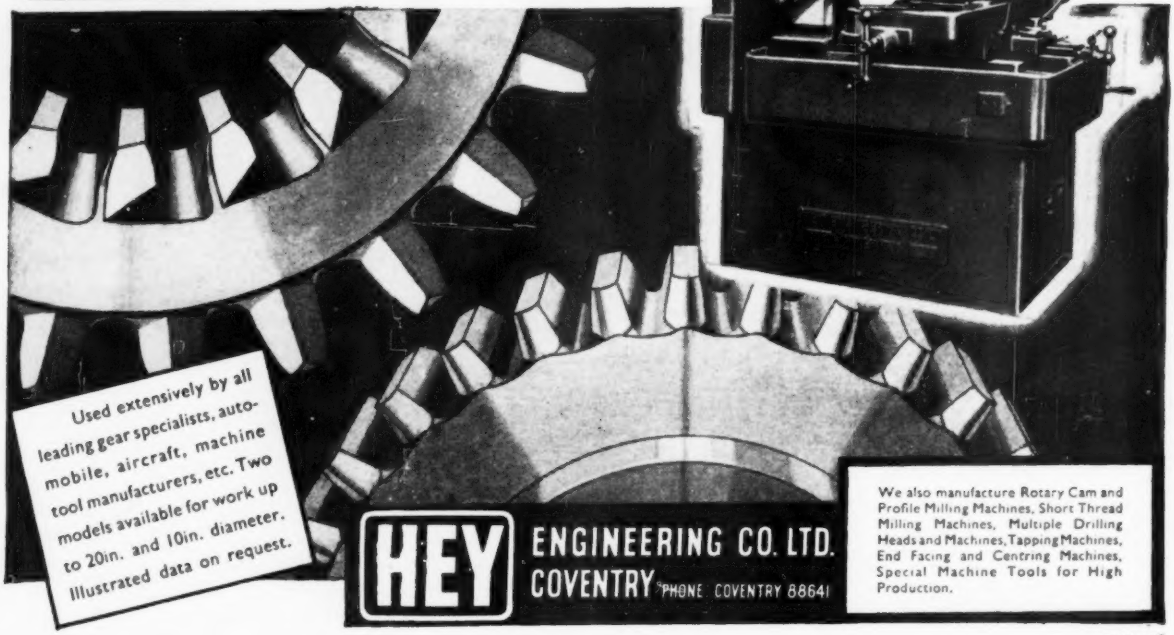

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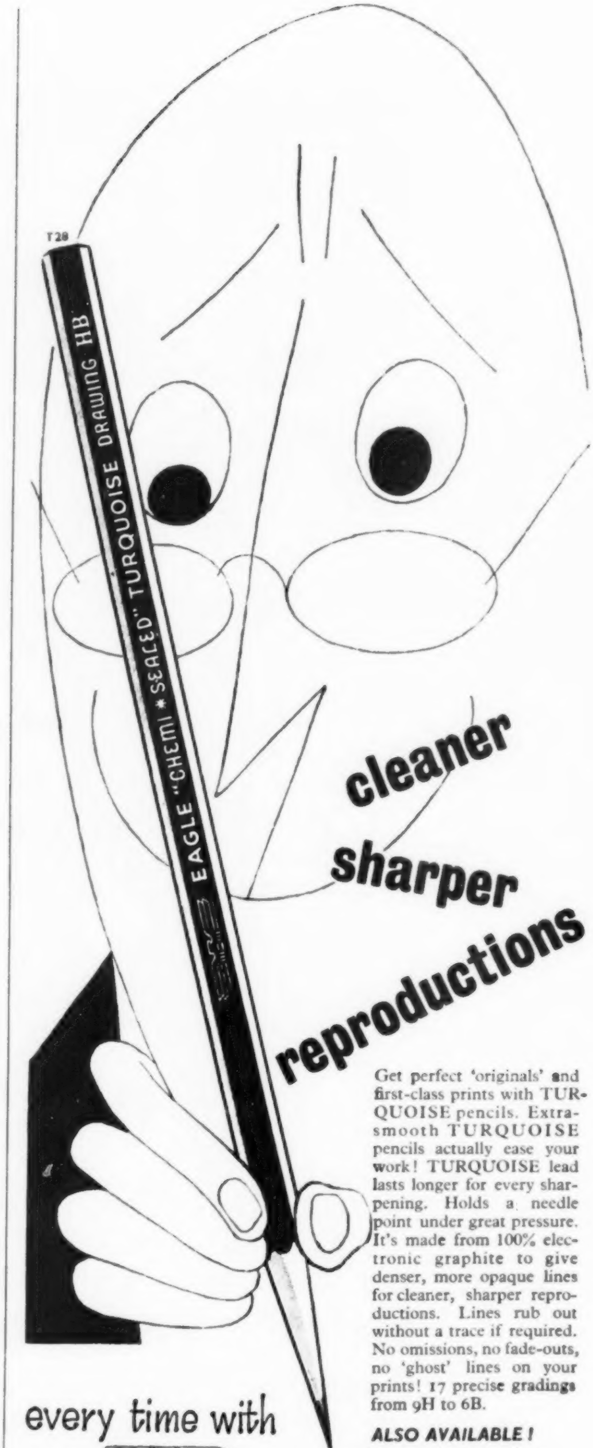

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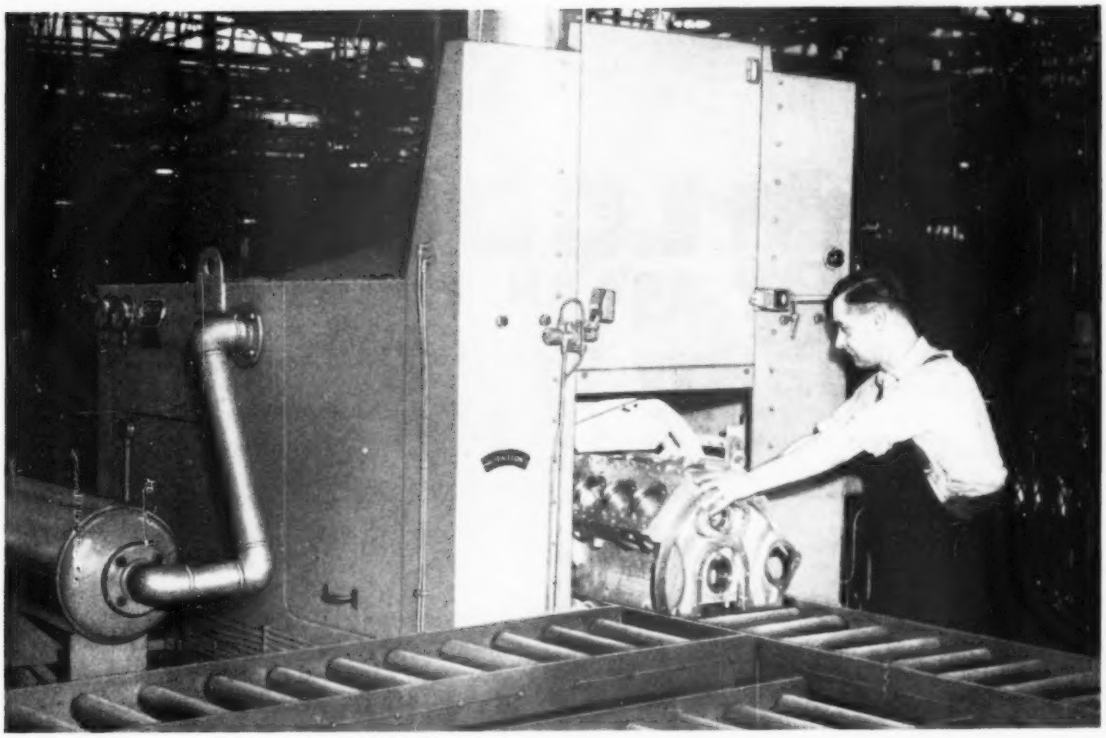
THE NEW ROLLS-ROYCE ALUMINIUM ALLOY CYLINDER BLOCKS ARE CLEANED AND DEGREASED BY A DAWSON MACHINE



The aluminium alloy cylinder blocks of the Rolls-Royce Phantom V and Silver Cloud II are cleaned of swarf and cutting-oil after machining by this Dawson high pressure jetting machine. Inside the machine cylinder blocks are continuously rotated and as they move round they are subjected to an intense jetting treatment from batteries of jets accurately positioned so that no surface or recess, internal or external, escapes the powerful cleaning action. An important piece of equipment on the machine is the Dawson cylindrical pressure filter (patent pending). This is principally a perforated cylinder over which is fitted a finely woven nylon mesh bag, and the high fidelity filtration provided is particularly suitable for the very fine swarf produced in the machining of the aluminium alloy cylinder blocks.

For full details of a Dawson machine for your purposes write to Drummond-Asquith at the address below.

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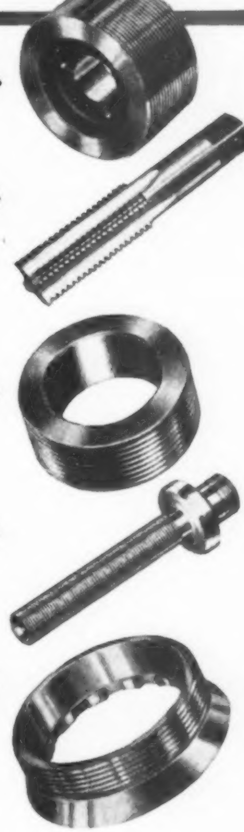
Thread Grinding Machines

save money on parts like these



Screw Plug Gauge
2$\frac{3}{4}$" dia. x 11 T.P.I. x 2$\frac{1}{4}$"
Whitworth Form

High Speed Steel Tap
1" x 8 T.P.I. x 2$\frac{1}{2}$"
Whitworth Tap
Limits BS949
Grinding Time 80 secs.

Thread Crushing Roller
3" dia. x 8 T.P.I. x 1$\frac{1}{8}$"
American Form

Micrometer Screw
10mm.x0.5mm.x40mm. long, S.I. Form
Grinding Time 6 mins

Internal Combustion Engine Valve Seat
1$\frac{3}{4}$" dia. x 20 T.P.I. x $\frac{5}{8}$"
Whitworth Form
Grinding Time 50 secs.

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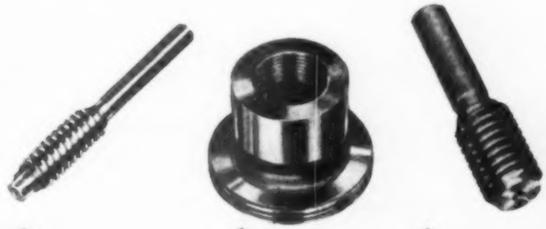
They will accommodate a range of work extending from the finest threads used in precision instrument manufacture up to a maximum capacity of 14" diameter by 72" long.
The machines embody the latest advances in toolroom and production thread grinding technique and are based on many years of research and development.



Steering Worm
26mm. x 6mm. x 66 mm. long
L.H. Worm Form
Grinding Time 3 mins.

Internal Threaded Component
1$\frac{1}{2}$" dia. x 16 T.P.I. x $\frac{1}{2}$" Unified Form
Grinding Time 4 mins.

Screw Plug Gauge
1$\frac{1}{2}$" dia. x 4 T.P.I. x 2" Acme.

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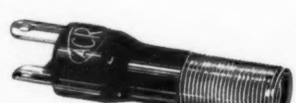

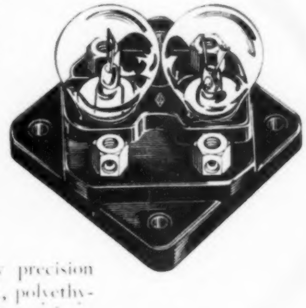

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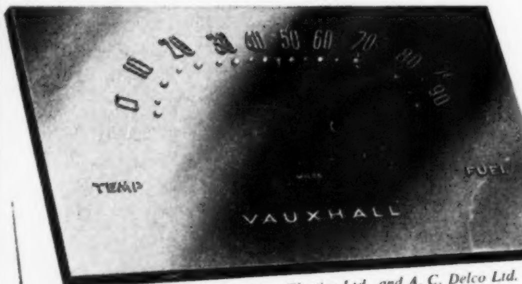

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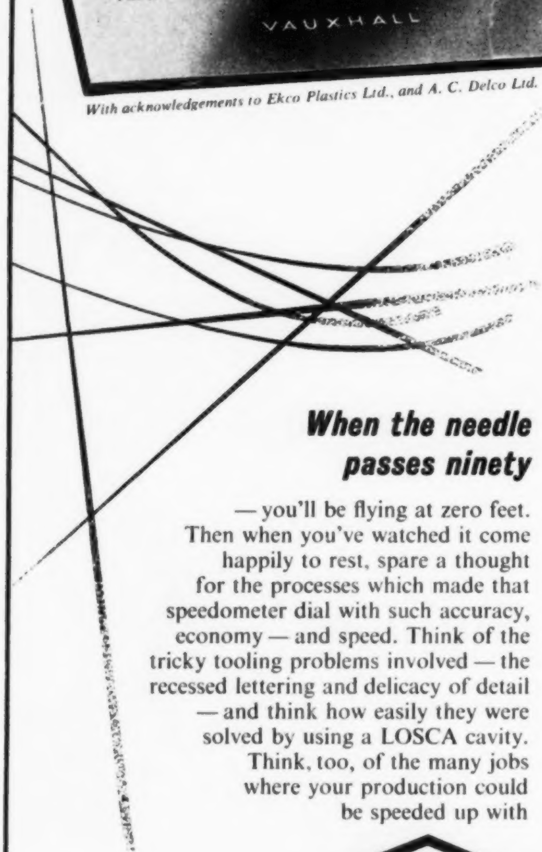

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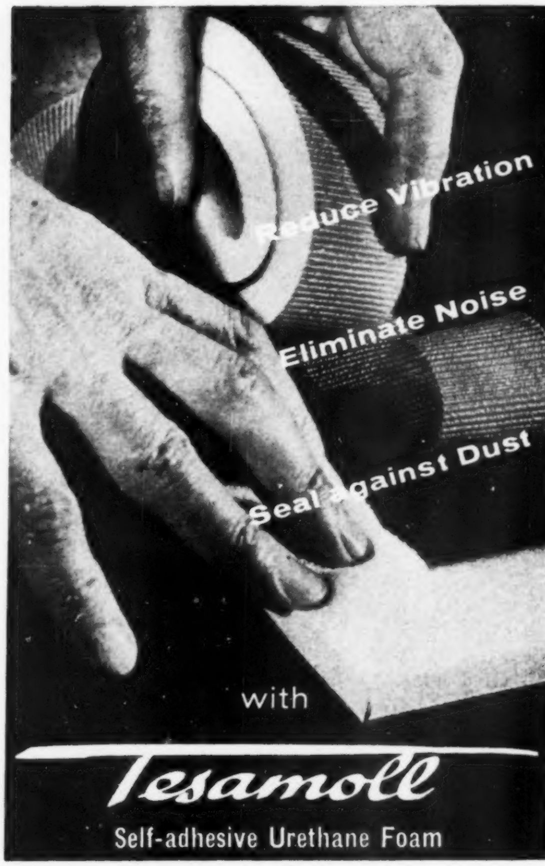

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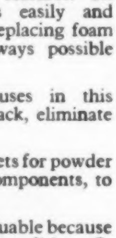

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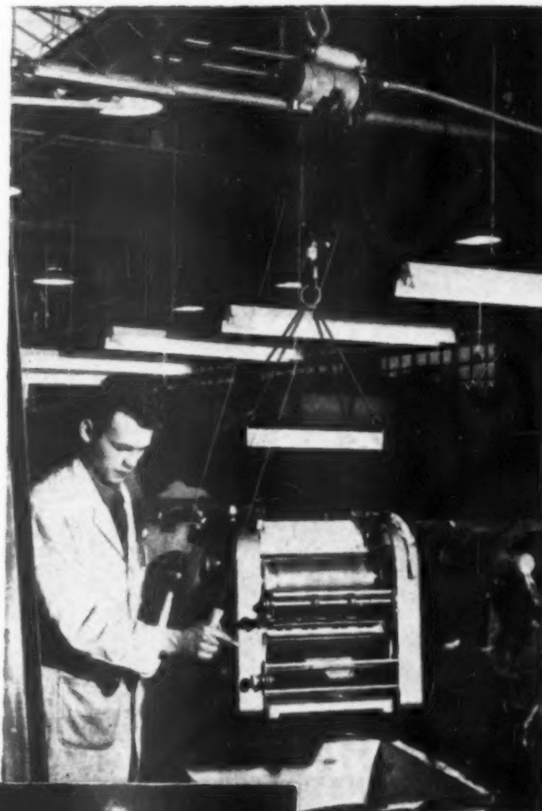

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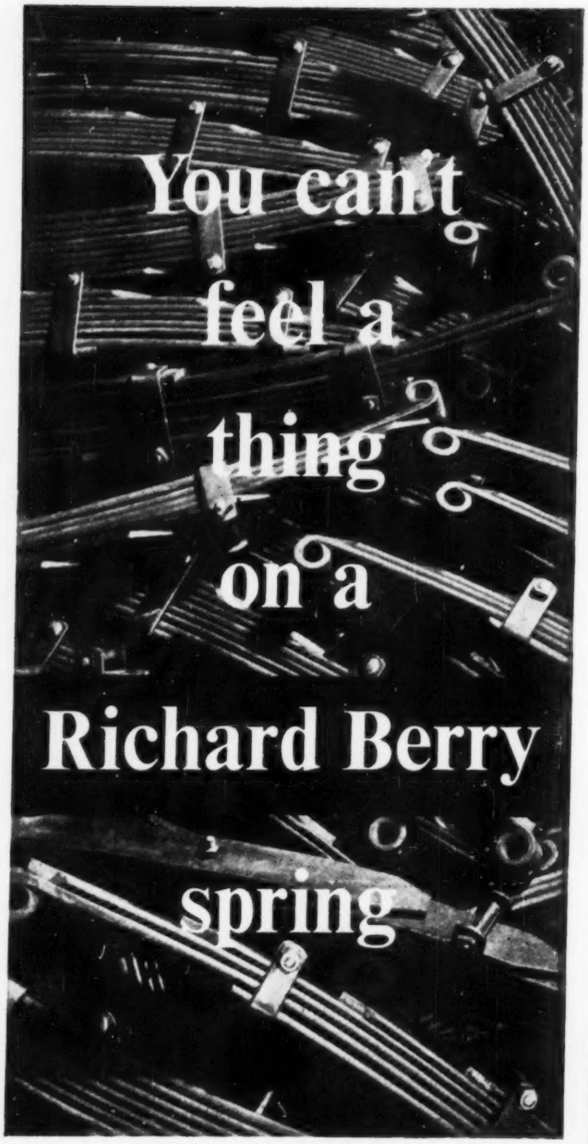

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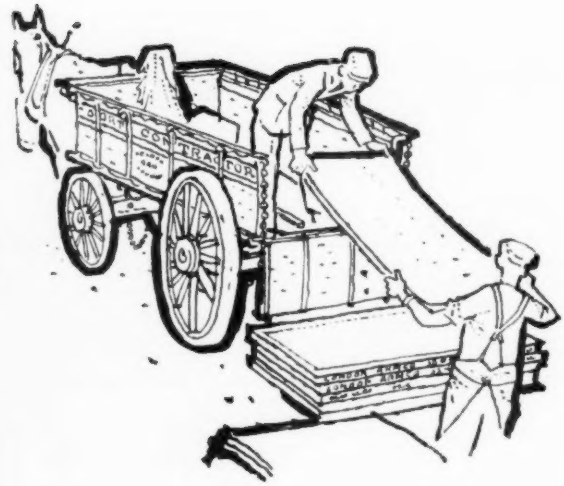

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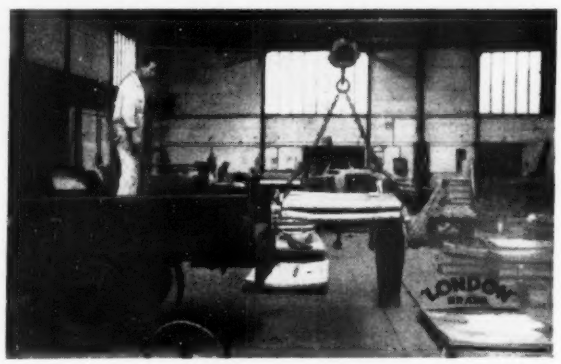

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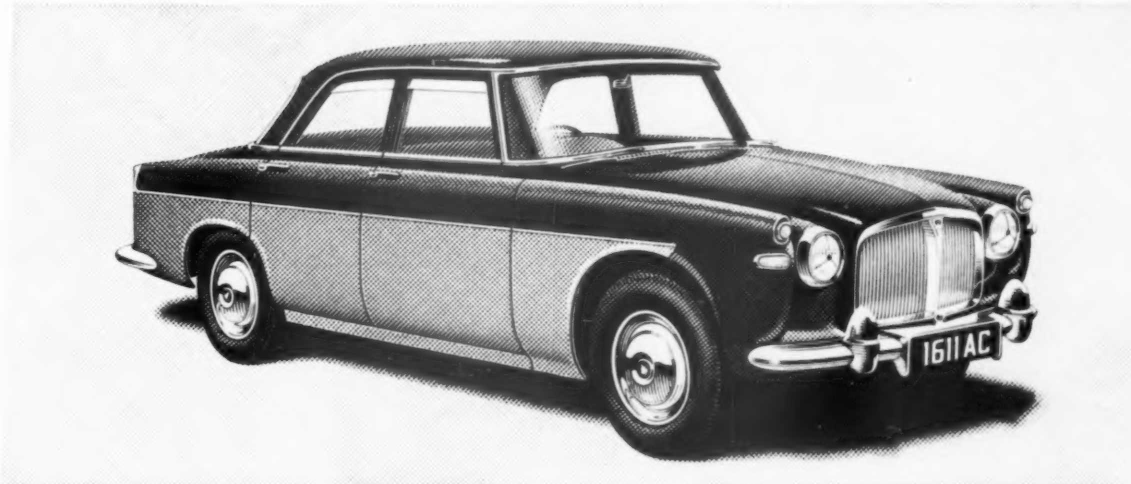

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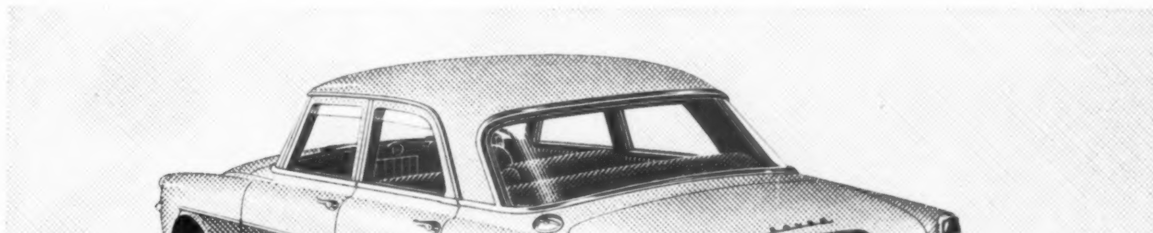

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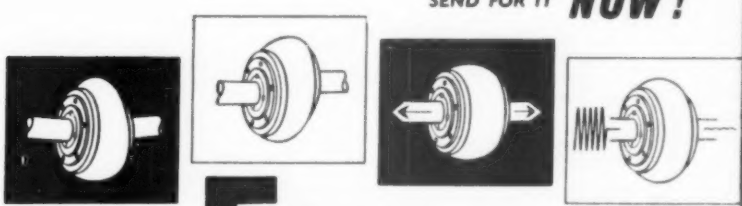

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SALARY commensurate with age and experience; the Company operate the normal fringe benefits, and housing assistance may be considered.

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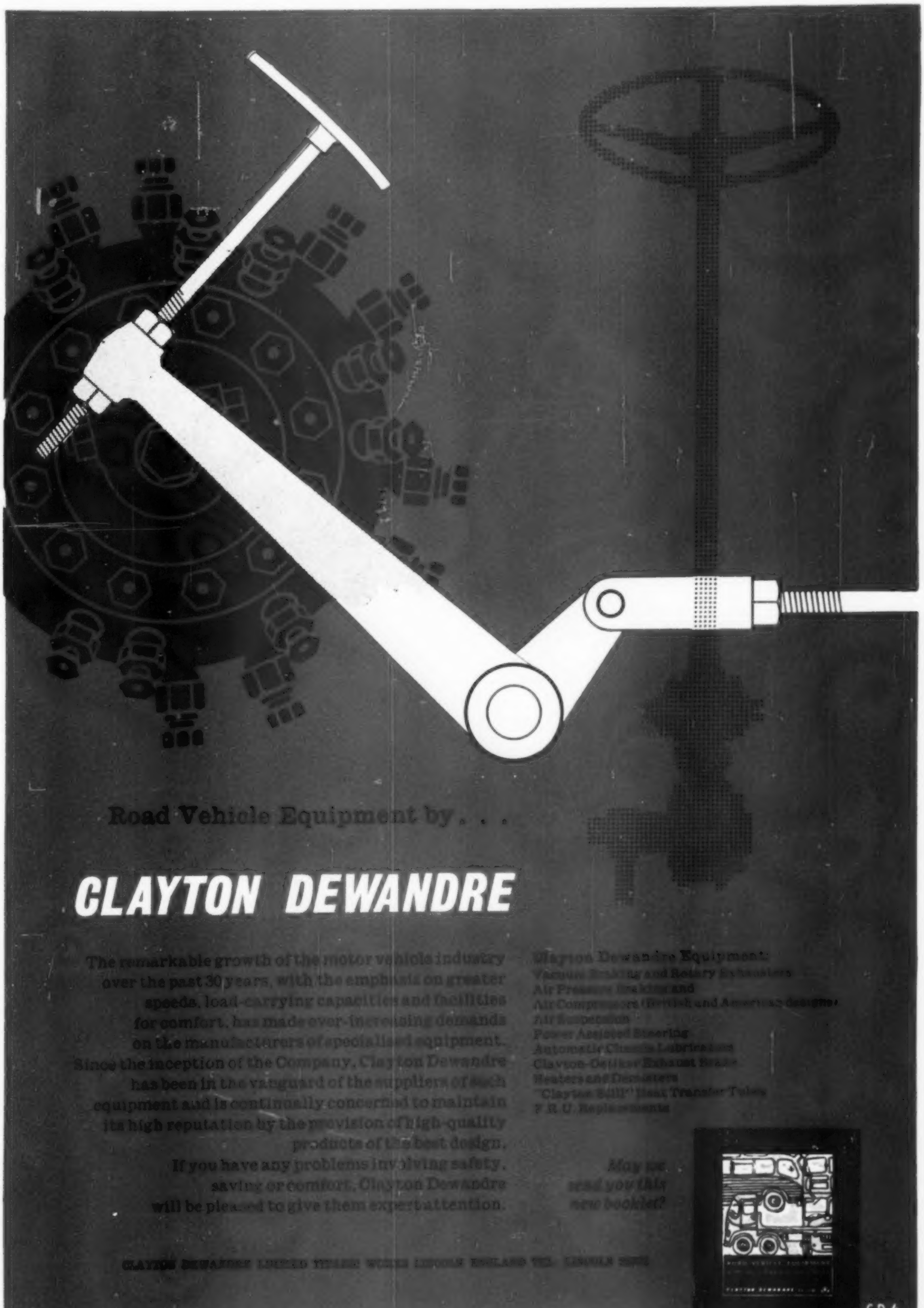

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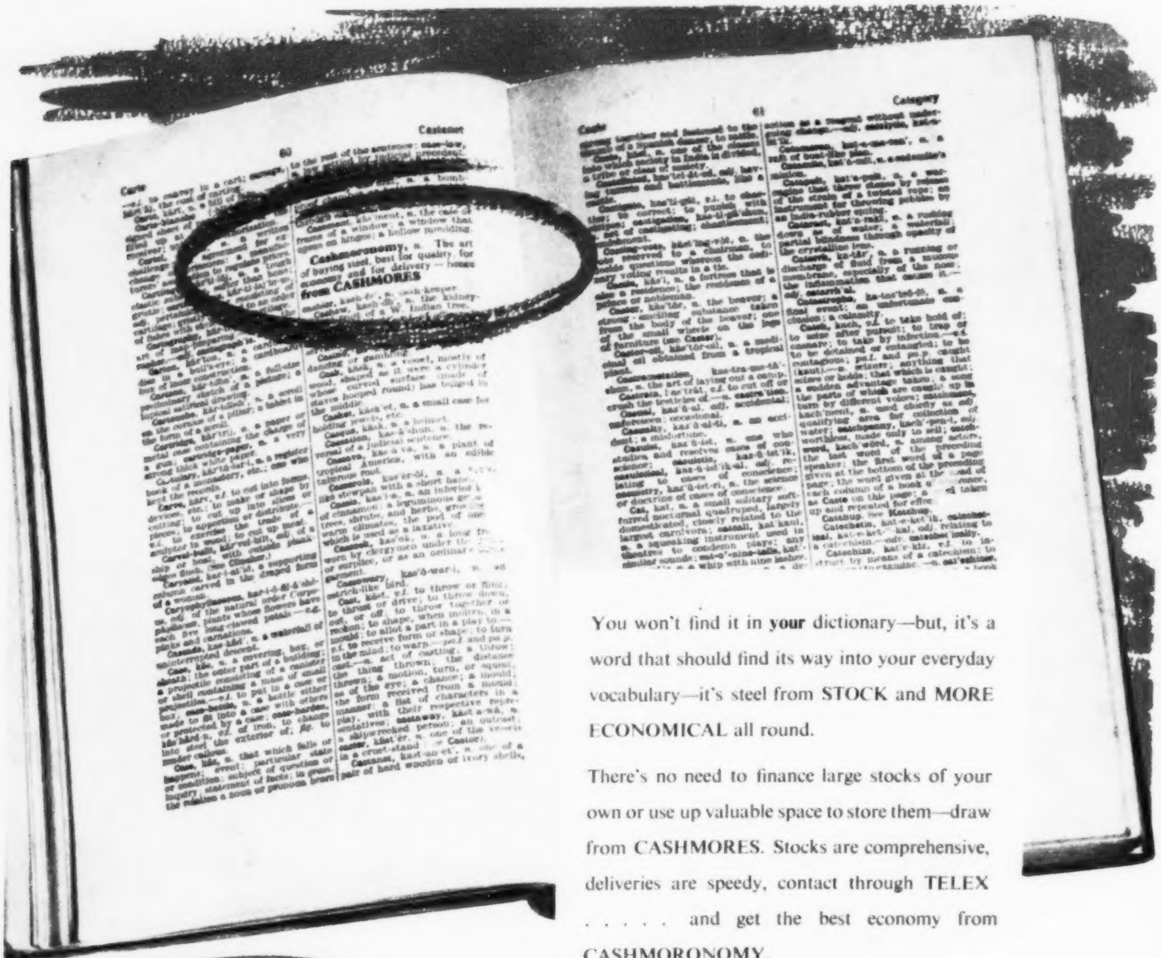

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